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# PROCEEDINGS

OF

# THE ENGINEERS' CLUB

OF

# PHILADELPHIA

## VOLUME XXI

EDITED BY THE PUBLICATION COMMITTEE

PHILADELPHIA
THE ENGINEERS' CLUB OF PHILADELPHIA
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PROCEEDINGS

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# DEVELOPMENT OF THE BRILL SYSTEM OF TRUCKS FOR ELECTRIC MOTOR CARS.

WM. H. HEULINGS, JR.

*Read October 3, 1903.*

DURING the Centennial Exposition several types of steam motor cars were put in use on the streets of this city. The Vice-President of the J. G. Brill Company, Mr. Jno. A. Brill, saw that if cars were to be self-propelled a framework would be required separate from the car body to carry the motors, as it would not do to connect the motors directly with the car body; the framework of the cars must be as light as possible, and therefore the vibrations and straining of the motors would quickly rack the car to pieces.

Street railway men thought Mr. Brill's idea not practicable because the motors would be brought too near the pavement and would therefore become clogged with dirt; they also thought an independent truck would be too cumbersome to use under light cars. It was not until 1885 that the idea was presented in anything like a complete form, and not until two years later was it accepted by any of the street railways or manufacturing companies. In 1887 two cars were built for Scranton with motors upon the trucks; before that, Vanderpoele built two cars with the motor set upon the front platform and con-

nected with the axles by chains and sprocket wheels; the strain of driving was thrown upon the body of the car—in fact, upon the front platform timbers; the extra weight thus carried so far from point of support was bad, and the cars could be run in but one direction. The racking and straining quickly shook these cars to pieces. In Sprague's early electric cars the motors were hung from the body and drove the axles through gears, but as in the Vanderpoele experiment, the strains were thrown on the car framing.

The first trucks which we built had each pair of pedestals cast in a single piece and bolted to sub-sills which were connected at either end by straight crossings, each pedestal enclosed a coil spring, and therefore four pairs of coil springs comprised the spring arrangement; the side bars were set very low and secured under the pedestals; the motor was hung on the axle and supported by springs and links from a channel iron crossbar at the center. This is what we now call "nose suspension." The truck was the starting-point of the mechanical success of electric motors and street cars. We built several hundred of these trucks, some of which are running to this day and giving good service. It is an interesting fact that the right method of motor support was adopted with this first truck and is the method which is now in universal use. Thus the independent truck was established in street railway practice.

Among the changes which quickly followed, and which were destined to be permanent features of this type of truck, were the abandonment of the enclosed pedestal springs and the adoption of spring posts. This necessitated the use of post stays, or lower chords, which, before the use of solid side frames, were trussed to the upper chords; the journal boxes were constructed with ears which carried the springs as in the old horse-car method; the base of each box was rigidly connected with the side frames, but this method did not give sufficient stability to the support of the car body, nor was there enough strength in the connection between the frames and the boxes to keep the truck square.

It had appeared necessary to preserve the continuity of these side bars. Experience proved that the boxes must work in jaws which must be an integral part of the side frames. This step was a radical departure which embodied the correct principles of all truck construction; namely, the independent frame, in addition to carrying the motors, must keep the boxes and axles in parallel relation; in other words, the squareness of the truck must depend upon the truck frames.

The axle-box yokes in the side frames were necessary not only for truck squareness, but also to permit the body of the truck to be lifted off the axles so that the motors might be inspected and repaired in pits.

The early motors were arranged to be carried low, therefore the side frames were also carried low. Soon motors were constructed that could be carried higher, and, what was of supreme importance, were completely encased. The encasing of the motors, protecting them from moisture and dirt, was the real beginning of the general use of electric motor cars, since it removed one of the chief obstacles. The motor supports were wholly depended on to connect one side frame rigidly with the other. The heavy motors that came into use with the use of larger car bodies brought too much stress upon these center crossings; therefore independent motor supports were placed upon the frame and straight crossings were used at the centers between the wheels and also at the ends of the frames outside the wheels.

An important advance on this construction was the introduction of diagonal crossings at the centers of the frames. A serious difficulty which for a long time baffled all attempts to overcome was the bounding motion, or oscillation, of the car body; there was evidently something wrong with the spring system. We were the first to recognize that the difficulty lay in the fact that the rail joints produced a rhythmic motion in the coil springs; we therefore introduced slower acting elliptical springs. This discovery was made about the same time we commenced making solid forged side frames; therefore it was a simple matter to lengthen the extensions and mount the elliptical springs at the ends of the extensions, thus breaking the rhythm set up by the coil springs, and to a large extent preventing oscillation. At the same time the elliptical springs extended the spring base. Later on the full-elliptical springs were superseded by semi-elliptics, which still further extended the spring base and were slower acting.

The correct principle in all truck-building is to have the frames support the car body as nearly as possible over the points where they are themselves supported.

When axle-box yokes were first adopted, rubber cushions were interposed between boxes and yokes, as no way of carrying the frame upon springs had been devised, and the importance of absorbing vibrations and shocks before they reached the frames was not realized. Rubber was a poor makeshift, however, and soon careful attention was given to this part of the spring arrangement. After various experiments, a satisfactory method was adopted of supporting the frames on

large-diameter coil springs set in pairs in ears, cast on both sides of the journal boxes; by this means the truck frame was carried low, and therefore the car body was carried low—a very essential matter, since the single truck is mostly used in city service where it is necessary to have the car steps as low as possible to facilitate ingress and egress. These coils being in pairs, the boxes were held in an upright position enabling them to work freely in the jaws.

While the single truck was being developed, the necessity for longer car bodies arose, requiring pivotal trucks. The height of cars could be little increased, space between the tracks could not be widened, and the radii of curves must remain practically the same as before. How to find room for double trucks to radiate under narrow cars was the

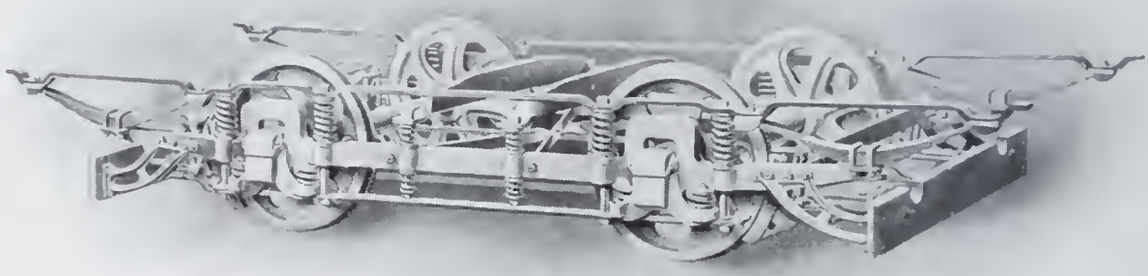


Fig. 1.—Non-oscillating Truck for Four-wheeled Cars (No. 21-E). Solid Forged Side Frames.

problem. Little was to be learned from steam practice. The limitations of operating on streets made the case entirely different, requiring the evolving of new principles of construction throughout. To give room for the motor and to allow the trucks to be located near the ends of the car body, and yet avoid the steps, were the reasons for placing the bolster out of center in the first pivotal truck which was built. This resulted in loss of traction, as the motor was applied to the wheels carrying the smaller proportion of the load; it was, in fact, a true "minimum traction" truck. The advantage of having ample tractive power was quickly discovered, and the next type was the "Maximum" Traction Truck—the first of its kind, unique in idea and design, the truck consisting of a pair of ordinary sized driving wheels and a pair of pony wheels with the weight eccentrically distributed

so that the large wheels carried nearly all of the load, the pony wheels bearing just enough to enable them to guide on the track. There was no bolster, the load being carried on side bearings over the journals of the drivers; a pivotal plate over the rear axle took none of the load, its office being merely to take the draft of the truck. While this arrangement enabled one end of the truck to swing clear of the sills of the car body in operation, it was found that the springs at the sides of the axle boxes of the pony wheels interfered with the running-board, or step, of open cars; it therefore became necessary to make other disposition of them, as the truck was limited to use under closed cars. This difficulty was overcome by narrowing the upper chord at the forward end

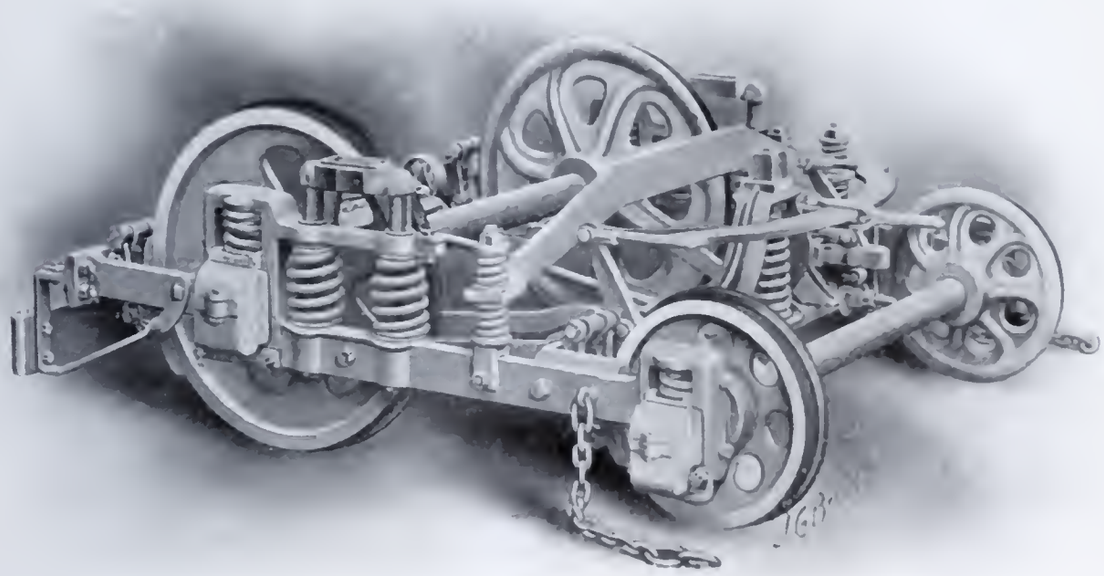


Fig. 2.—Maximum Traction Truck for Low and Narrow City Cars (No. 22). Solid Forged Side Frames.

and seating the springs on the front crossing. This, however, was a temporary expedient. Permanent corrections were the doing away with the drawing plate over the rear axle which interfered with the motor and substituting a radial casting by which the truck was drawn, and by the use of guides secured to the car body for the side bearings. The truck was thereby made to radiate from an imaginary point located about six inches inside the driving axle. This was the first truck to have solid forged side frames. The composite frames were so unsatisfactory, bolts and nuts could not be kept tight, and, difficult as the forging of such frames was, we believed that the success of the truck depended upon it. We shall have more to say later of forged frames.

The greatest problems which confronted us were the brake system and proportioning the weight upon the pony wheels. Discouragement followed discouragement; the pressure was the same on the large and small wheels, and, as a consequence, the small wheels had a disposition to lock and slide, long before the car could be brought to a standstill. This was decidedly objectionable because of the small wheels rapidly becoming flat in places, and because of the racking and the jolting of the truck while the wheels were skidding. Derailments continued through a long series of experiments. At length differential levers were devised which divided the pressure on the small and large wheels in proportion to the weight resting on them. This was entirely successful. A pair of coil springs were placed on the side frames close to the large yokes through which were spring posts which carried the side bearings. This brought the weight between the center of the truck and the driving wheels, making the proportion on the pony wheels about 25 per cent. A spring compression post directly back of the pony wheels' axle increased the load upon them on curves by means of a "V" plate attached under the car. The frame was mounted on journal springs.

Eight or nine years ago, roads in various parts of the country commenced extensions to neighboring towns, some of them acquiring private rights of way. This was the beginning of the interurban electric railroading which has progressed so marvelously. High-speed, long and heavy cars were required for this form of service, and therefore trucks for four-motor equipments per car were needed. The first type we designed for these requirements was a side-bearing swing bolster truck with six-foot wheel base and cast-steel frames; this was the first passenger truck to have the side frames cast in a single piece comprising upper and lower chords, jaws for the boxes and extensions. Careful observation of the operation of this truck and increasing opportunities for studying the conditions of such service convinced us of the need of an equalized truck. Apparently, now was the time to look to steam practice. The so-called "Master Car Builders'" equalized truck was in general use, and is to-day, but after exhaustive experiments and tests with that type we turned from it, assured that the principle of supporting the frames on equalizing bars was incorrect. The frames tilted as much as five inches under rapid brake action, relieving for the time one pair of wheels of part of their load. We found other faults: The steel hangers of the bolster, although allowing a side swing, did not cushion the motion; in taking curves, the side swing

fetched up with a jerk which jarred the car and forced the wheel flanges violently against the rails, and frequently the bolsters would strike the wheel pieces. The draw-bar pull of the locomotive has saved many a derailment. We found that the tremor so noticeable in trucks of this character was caused by the equalizing bars resting directly on the journal boxes, holding them rigidly at right angles and preventing free vertical movement. Cars are often violently shaken when coming to a stop by frames tilting and the boxes binding in the jaws, because the equalizing bars prevent their assuming the same incline with the jaws which are an integral part of the frames. The truck which we produced, and which wide experience has approved, radically differs from the former equalized swing bolster truck; each side frame is made of a single piece of wrought or cast metal with angle iron tran-

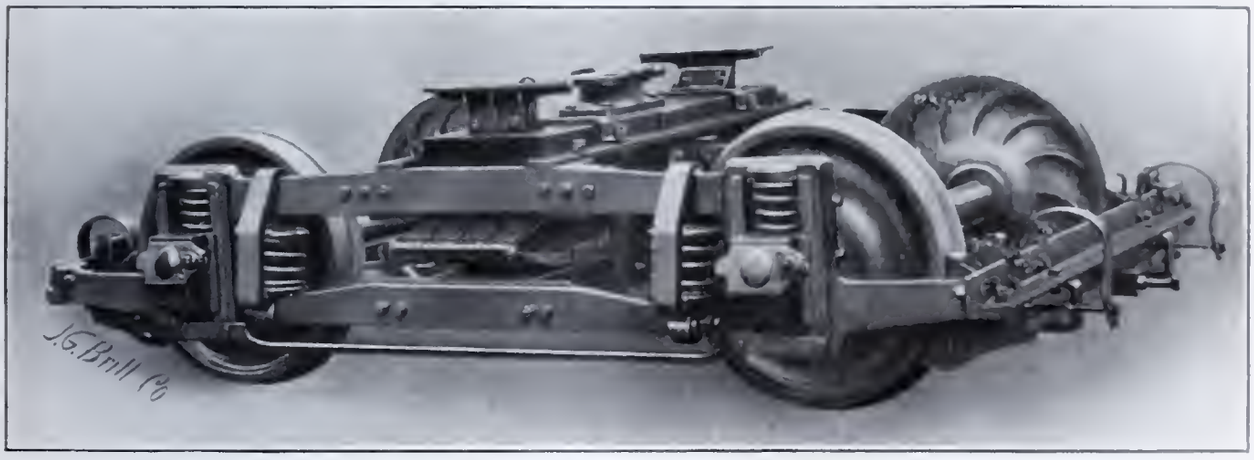



Fig. 3.—High-speed Interurban and Steam Passenger Truck (No. 27-E). Solid Forged Side Frames.

soms, end-pieces and tie-bars. Journal springs carry the frame, affording a spring base as long as the wheel base. The equalizing bars are suspended by spring links from the side frames near the yokes, giving a leverage in favor of stability. The spring plank is rigidly secured to the centers of the equalizing bars and carries the bolster in the usual fashion on elliptical springs. The links at the ends of the equalizing bars swing the bolster, and at the end of the swing the springs in the links cushion the motion. The shallow wheel flanges that are necessary on many of the high-speed electric roads on account of using both girder and "T" rails, the many curves usually encountered, and the fact that there is no draw-bar pull to steady the car render it necessary to have a perfectly equalized truck, and we believe we have found it in this type known as the Brill No. 27 Truck.

This truck was also used for several years after its advent under long and heavy city and suburban cars, which required a four-motor equipment. The long wheel base was objectionable for city service, but seemed necessary on account of using a pair of motors per truck. In 1899 we produced a short-base truck which supported the motors on the end-pieces. It was an equalized truck of the same system as the high-speed truck, but modified to suit the requirements of narrow and low-carried cars. Instead of equalizing bars, semi-elliptic springs are used which support a bolster of truss form, thereby doing away with the spring plank. By having no spring plank, space is obtained

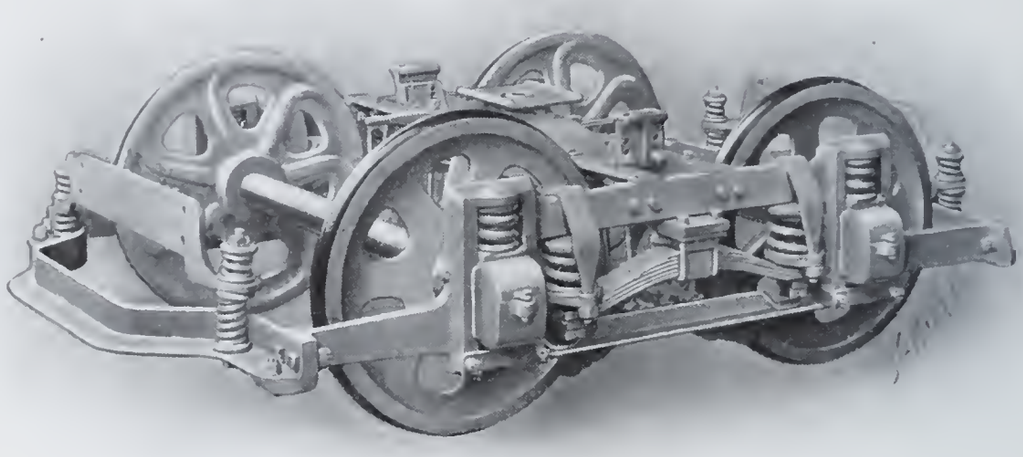


Fig. 4.—Truck for Fast and Heavy City and Suburban Service (No. 27-G). Solid Forged Side Frames.

for inside-hung brakes; the semi-elliptics are suspended from the side frames by spring links.

During the development of these types we worked out brake systems which respond quickly to the operating arrangements and insure an equal pressure on the wheel of the entire surface of each brake shoe.

The journal box came in for a large share of attention, and ultimately a box was devised that was dust-proof and self-oiling.

Before going further let us mention some of the things which have come into general use, which we have contributed to the art of modern truck-building:

The idea of independent trucks for motor cars; the use of spring posts; pedestals made part of the side frames; the hanging of brakes

from side frames; the placing of plate springs on the frame extensions; supporting the frame on springs; the maximum traction idea; the side frame cast in a single piece.

We have patented and retain for our own use the systems and special features of the various types of trucks.

We have left to the last the discussion of truck frames because the subject relates to all the trucks. In an article published in the "Street Railway Journal" of May, 1899, Mr. Jno. A. Brill called attention to

Fig. 5.—Welding a Side Frame of the No. 21-E Truck.

a remarkable parallel in the successive steps by which locomotive and electric truck frames have been developed. He showed that the frames were the outgrowth of the requirements of constantly enlarging lines of service. At first rivets were used everywhere to hold the parts together and the frames were made up of materials ready at hand in the market. A multiplicity of parts riveted together formed what seemed to be a solidly connected whole. It is an odd fact, in view of the service the modern electric truck has to perform, that many builders of the present time are working with the same limited con-

ception of the problem as did the locomotive builders in the early days—the controlling idea, maximum power and convenience of manufacturer. In less than six years' experience American locomotive builders found that such frames were not proper foundations upon which to mount an engine. In the year 1840 the Baldwin Loco-

Fig. 6.—Forging a Yoke for a No. 27-E Truck Side Frame.

motive Works were using solid iron frames, and this practice has been followed by the locomotive builders of this country ever since. Every conceivable form of truss, built-up, or cast-metal work, has been used by truck builders in the endeavor to evade the expensive and difficult manufacture by the solid forging process. The builders of trucks for steam roads are also included. The gusset plates and

forged transoms of their trucks are not successful in keeping them square, and squareness is the prime essential in all truck construction. Trusses and riveted work do very well so far as a vertical static load

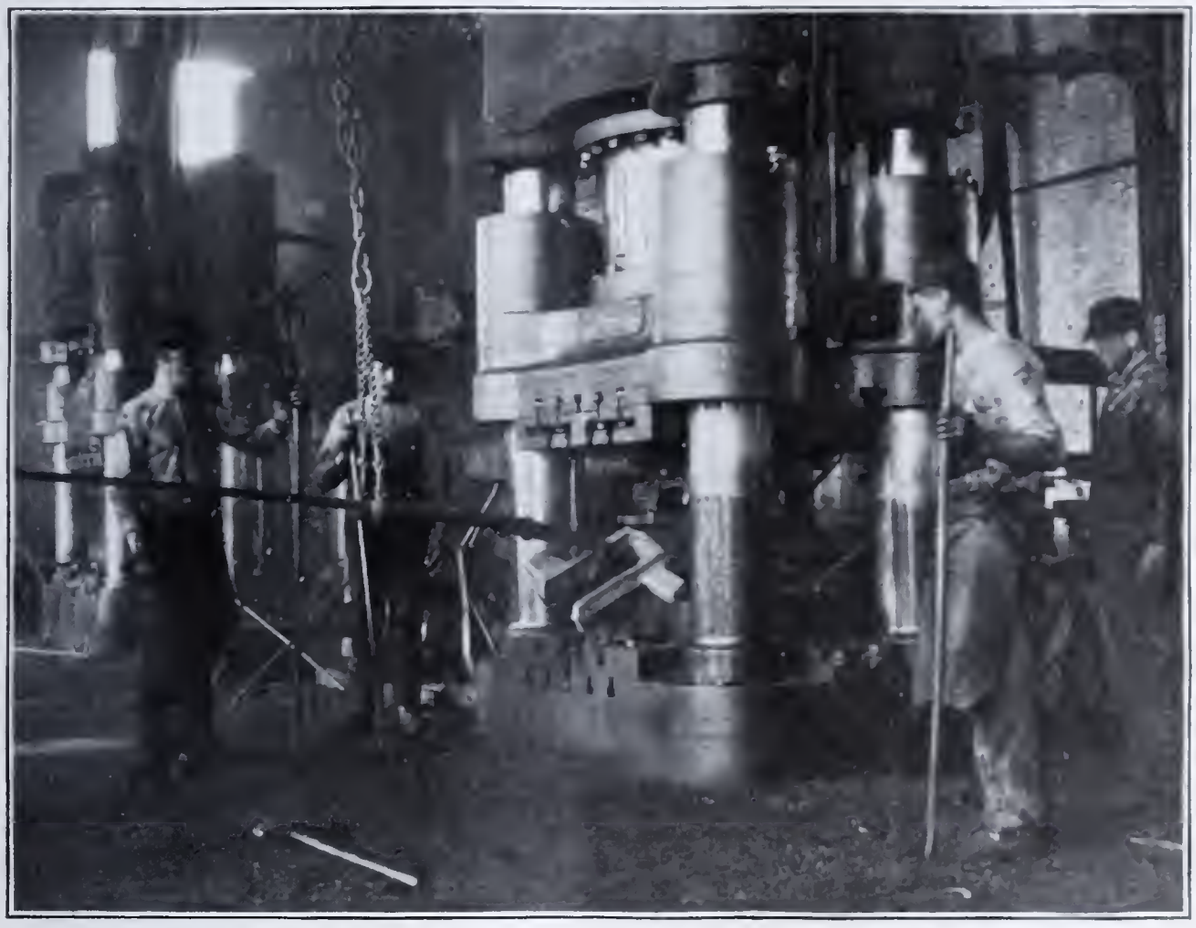


Fig. 7.—Pressing a Yoke for a No. 27-E Truck Side Frame.

Fig. 8.—A Solid Forged Side Frame of the No. 27-G Truck

is concerned, such as in bridge-building; but where strains come from every direction, and shocks and vibrations have to be constantly endured, such methods of construction are radically wrong—a statement which has been amply proved in practice. It is impossible

to overstate the importance of having frames capable of maintaining their original squareness: Rivets loosen; heads sheer off; bolts work loose; and as soon as the frames yield, deterioration commences and proceeds rapidly, because any variation from absolute squareness allows the axles to get out of parallel, the motors then lose their proper alignment, the journals are forced out of true bearing, the boxes bind in the jaws, the wheel flanges out of parallel with the rails, grinds continually against them, and vibration is increased by friction. For many years we used cast-steel frames for our pivotal trucks, and are still using them largely, but we find that crystallization is sure to take place. About four years ago we built a lot of high-speed trucks for the Buffalo and Niagara Falls Electric Railway which have been giving excellent service, but recently many of them have broken in one place or another. In a paper read before the Pittsburg Railway Club last April, Mr. A. W. McCaslin, master blacksmith of the Pittsburg and Lake Erie Railway, said:

"If tensile and torsional strength were the only requisite of a perfect material for locomotive frames (cast), steel would, indeed, be the ideal metal; but where shocks and vibrations are factors, there is danger in its use. . . . On one of our neighboring railroads they have had within the last six months, thirty-five steel frames break on their consolidation engines, while only one wrought-iron frame has broken."

A motor truck frame has to withstand more severe shocks and vibrations than a locomotive frame, and carries a much heavier load in comparison. Of the thousands of wrought or solid forged frames we have made, only a small fraction of 1 per cent. have broken or in any way needed repairs. Cast-steel frames are better than riveted or built-up structures, because they keep square, do not sag, and cannot be shaken apart. Solid forging is using metal with a fiber to it and toughening it while being shaped under tremendous pressure.

## DISCUSSION.

The President.—The Club is under many obligations to Mr. Heulings for presenting this paper, and I am equally sure he will be glad to hear from any member of the Club who wishes to discuss the subject.

Robert Schmitz.—I should like to ask Mr. Heulings what diameter wheels were used on the Schenectady line that made the ten miles in eight minutes.

Mr. Heulings.—Thirty-six inches.

Mr. Schmitz.—What is the usual diameter?

Mr. Heulings.—Thirty-three.

Henry H. Quimby.—I should like to ask Mr. Heulings how the trucks are braced to hold them square.

Mr. Heulings.—Braced with diagonal tie-rods directly across the center, and tying vertically from a point about seven inches inside of the spring.

Mr. Quimby.—Were they adjustable rods?

Mr. Heulings.—No; we forge them up to the place and bolt them there.

Mr. Quimby.—How are they secured?

Mr. Heulings.—To the side of the frame by bolts. I have never known of them getting out of place except in a collision. The greater portion of strain is taken up there, and in addition we have end-pieces from which the brakes are hung. There is a diagonal brace across the entire truck. That applies to the 21 E trucks or single-truck. The double-trucks are held by the angle irons across the ends of the truck outside.

Mr. Quimby.—The holes for those bolts are drilled?

Mr. Heulings.—They are drilled originally and reamed and driven bolts are used with lock-nuts.

The President.—I would like to ask Mr. Heulings what is the weight of the larger cars used by the Traction Company in Philadelphia—the latest pattern of car.

Mr. Heulings.—Do I understand that to be in operating condition?

The President.—Yes, complete with motor equipment.

Mr. Heulings.—I can give the exact car body—about twelve thousand six hundred pounds; each one of the trucks about forty-three hundred and fifty pounds. The motor equipments would weigh ten or eleven thousand, and air-brake equipment should be four hundred. Thirty-two thousand seven hundred is the total. About a 16-ton car.

James Christie.—Mr. Chairman, I did not have the pleasure of visiting the Brill Company's works with our members, and consequently, am not familiar with some of the matters under review. I would like to ask Mr. Heulings a few questions. Are the billets referred to, wrought-iron or steel?

Mr. Heulings.—They are soft steel.

Mr. Christie.—Does your Company manufacture a track brake?

Mr. Heulings.—We have made quite a number and still continue to make them.

Mr. Christie.—I have been traveling a good deal lately on the Pittsburg street railways, and, as you are aware, especially on the Allegheny City side, they have very steep grades, and run at high speeds. I observe an extensive use of the magnetic rail brake, and think it is superseding the old wheel brake. Doubtless the action of this brake is under the control of the motorman; nevertheless, the cars are usually stopped so suddenly that the unfortunate passengers who have to stand and hold on to the straps, have difficulty in maintaining their equilibrium. These brakes have the advantage of largely overcoming the trouble due to flattening of wheels. Referring to Mr. Heulings's objections to steel castings, I am of the opinion that a good sound casting, properly made and properly annealed, approximates closely in physical properties to that of a forging. Steel castings are now largely used instead of forgings. The casting has at least one advantage, and that is that you can form your pattern to any desired shape, flanging it and modifying its section to suit the intended purpose in a

manner that would be almost impracticable with a forging. Can Mr. Heulings tell us what material for brake shoes has been found the most effective, fulfilling the purpose of the brake and reducing the tendency to flatten or unduly wear the wheel?

Mr. Heulings.—I will take up each of the questions separately. The track brake is not in reality a track brake, as might be conveyed, but is a combination electric track brake. I have seen it myself. If operated properly, the motorman could bring the car to as comfortable a standstill as an ordinary hand-car. The man that understands it, knows the condition and controls it; that is, the track brake put on the market at the present time by the Westinghouse Brake Company. As far as cast-steel is concerned as compared to a wrought-iron forging—my experience has been only in reference to trucks. I have known where wrought-iron trucks have not failed and cast-iron trucks have failed. As regards brake shoes, the most satisfactory shoe we have found is the soft gray iron brake shoe with pieces of wrought-iron let into the face. It increases the life and does not wear out the wheel. There have been a great many different styles put on the market, but nothing has seemed to fill the bill so thoroughly as the small pieces of wrought-iron let into the surface of the brake shoe.

Thos. C. McBride.—I understand it is quite customary to straighten crooked cast-steel castings cold—probably while the inspector's back is turned; nevertheless I hear it is done very often. What effect has that on the life of the casting?

Mr. Christie.—I do not think it is good practice to straighten cold metals of the kind we have under consideration. Doubtless such straightening has been and always will be done more or less. All our mills straighten their structural material cold. It is endeavored, however, to straighten by roller process and avoid sharp bending as much as possible.

Francis Schumann.—I would like to ask Mr. Heulings whether the fracture in the steel frames occurred at the same point.

Mr. Heulings.—The fracture I referred to on the Buffalo and Niagara Falls trucks I think in ninety per cent. occurred in exactly the same place.

Mr. Schumann.—Near the boxes?

Mr. Heulings.—No, sir; pretty near the center of the frame—within a few inches of the center of the frame.

L. Y. Schermerhorn.—The trolley cars are very noisy; how much of this noise is due to the permanent way, how much to the trucks, and how much to the motor? It would hardly seem due to the rolling parts of the trolley, or to the wheels being brought in contact with the various joints. A very large part of the noise probably comes from the motor itself. I would like to ask if this assumption is correct.

Mr. Heulings.—A portion of the noise always comes from the motor. I should not think it is the greater portion. You will find more noise on exactly the same kind of equipment on some divisions than others. It is due to the absence of care in looking after the braking apparatus. The motor noise and the truck noise are radically different. The motor noise is a distinct buzz, and you can detect it above anything.

Mr. Christie.—Much of the noise in our electric cars comes from imperfect tooth-gearing. When flat faces are produced on the wheels, we hear the dis-

tinctive hammer due to that noise. The strain on the spur gears is very great, and when these are made of ordinary material, the curves of the tooth are soon flattened and the gears become noisy. The remedy for this is to maintain as much face of tooth as possible, and use very hard steel in the gears.

Mr. Hering.—It seems to me that among all those trucks shown in the slides, the most noisy is the maximum traction truck. There is a vibration set up when the brakes are applied, and it makes the whole framework rattle very badly. I would like to ask whether that has now been overcome. I notice this rattling on many cars in this city equipped with this maximum traction truck.

Mr. Heulings.—As I stated, the maximum traction truck is the most complicated we have. We have two different weights on the two pairs of wheels, and we have to arrange it in such a manner that all wheels will brake at the same time. There is a way to overcome it. This consists of a bracket casting which is bolted to the cross-bar which holds the brake beam down. As soon as it gets below, the rapid revolution of the wheel has a tendency to jar it up. This does not entirely eliminate but overcomes the difficulty very largely. The statement is correct, there is more rattle on a maximum traction truck than any other truck. It is due entirely to the brake apparatus.

Mr. Quimby.—What truck is used in New York city?

Mr. Heulings.—The maximum traction truck is used entirely in New York. I think there are seven thousand in operation in Greater New York at the present time, and they have largely overcome the brake rattling condition by keeping the castings thoroughly down. I don't think it would be possible to sell any other pattern of truck to the Metropolitan Street Railway or the Brooklyn Heights people. They have met the conditions thoroughly and are entirely satisfied.

Walter Loring Webb.—The maximum traction truck is generally put on with the large wheel toward the end of the car and the small wheel inside.

Mr. Heulings.—That is correct.

Mr. Webb.—I noticed the other day some cars in the city where the smaller wheel was near the end. I was wondering whether it was the same kind which was turned around for equalizing the wheels.

Mr. Heulings.—The real reason for that is (it is not a truck of our make; it is made in Chicago and is a center bolster truck)—the object in reducing the size is to get the wheels down so that they would clear the platform beams. That was the reason for decreasing the size. It would operate just as satisfactorily if they had larger wheels.

Mr. Hering.—Is only one pair driven or both pair?

Mr. Heulings.—Only one pair driven.

The President.—Has Mr. Heulings any objection to stating the extent to which these Philadelphia made trucks are used in foreign countries? I think it would be interesting to the members.

Mr. Heulings.—I am very glad to make the statement. It is certainly a great pleasure and I usually embrace every opportunity. Last year from Great Britain we received orders for about eighty-seven per cent. of the trucks used there. The remaining thirteen per cent. were divided up between five British

and three American builders. The large majority were with the wrought frame. That is the proportion of our British work.

Wm. C. L. Eglin.—When in London, in the year 1900, I went to a street-car exposition with an American engineer, and he pointed out a good many freak cars of peculiar form, and then after we had gone around, I went to look at the trucks and discovered that there were some twenty-three different car builders with the same truck, and that was made in Philadelphia.

Mr. Hering.—I move to extend a vote of thanks to Mr. Heulings, who is not a member of the Club, for his kindness in preparing this very interesting paper for us, and in conducting us around the works of his Company this afternoon. Also to the J. G. Brill Co. for the privilege of allowing us to inspect their interesting works, and for the courtesies extended to us.

The President.—I am very glad indeed to put that motion.

(The motion was put and carried unanimously.)

# FOUNDRY COSTS: THEIR ANALYSIS AND REDUCTION.

HENRY HESS.

*Read October 17, 1903.*

In order to economically manage a foundry it is necessary to know accurately the various elements of expenditure and, having these, to analyze properly their relation to one another and to the product. The manager is then in a position to check at once any rising tendency of the costs or to bring about a reduction, as the analysis points out an opportunity. No doubt, all of this can be, has been, and is being done successfully to-day by many a foundryman to the entire welfare of the business without any conscious or formal analysis or detail accounting. There are many managers of the old school who, through personal experience, a high order of native talent, and close touch with every detail, get along without other aids. But in these days of large and growing concerns, it is neither advisable nor safe to rely utterly on one man, no matter how capable, nor yet to the best interests of all concerned to burden the higher officials with the infinite detail work needed to get into sufficiently close personal touch with the entire working routine.

It is quite possible so to present the vital elements of cost that the managing head can at once grasp all salient features, see whether cost is stationary or not, and determine where effort must be applied to check a rise or bring about a reduction. The necessary work forming the basis of analysis can be readily performed by a very ordinary grade of shop clerk, once the routine has been fixed.

To start with, all of the elements of cost must be enumerated. It is well also to assign to each element a value, not so much with the idea that this value is absolutely correct, but rather to have some basis of comparison; experience may be relied upon to gradually bring about correct values. The figures given hereafter are to be taken as having merely an illustrative value; no attempt is made to provide a record of actual or proper costs.

In illustration, the elements of cost are divided among a few main heads as follows, it being understood that for actual work a subdivision more in detail must be used; to enumerate them fully is outside

the province of this paper, in which it is intended merely to present in general outlines a successfully used plan:

(*a*) General expense.
(*b*) Fixed salaries.
(*d*) Power.
(*e*) Miscellaneous materials
(*f*) Labor.
(*g*) Pig and other charging metal.
(*h*) Smelting material.
(*j*) Light.
(*k*) Recovered material.

The collating of the actual amounts of the various items as incurred is best done weekly rather than monthly or at other long intervals, as that will permit the recognition of a defect in time to trace it correctly to its cause and to apply a remedy. Should a longer interval be determined on, that should be four-weekly rather than monthly, in order to avoid the disturbing effect of the varying number of working days in different months, and also because it fits in better with the weekly pay accounts. Such charges as are based on a monthly rate can very readily be converted into an annual and from that to a weekly rate.

Apportionment of the various elements of cost to main divisions is made in accordance with readily apparent principles:

(*a*) General expense: Depreciation and interest charges.

(*b*) Fixed salaries: All salaries to persons having a fairly certain tenure of office; salaries to minor clerks that are likely to vary in amount should be entered under labor.

(*d*) Power: All charges directly connected with the power plant.

(*e*) Miscellaneous materials: Sand, flour, chaplets, wire, molders' implements, etc.; in fact, all materials not accounted for under heads *g* and *h*.

(*f*) Labor: All payments made to workmen and other persons. Includes all pay not taken care of under head *b*.

(*g*) Charging metal: Everything charged into the cupola, except fuel and flux; also all "medicine," whether added in the cupola or ladle.

Note.—For purposes of comparative analysis these materials should be rated at fixed values, although they will be purchased at more or less fluctuating rates. In order to take care of the difference between the assumed fixed and the actual fluctuating cost, the dif-

ference should be determined at suitable periods, and this difference debited or credited, as the case may be, as a "market equalizer" affecting the profit and loss account. Should the fluctuations be large, it will be advisable to make use of a "special charging account" to properly analyze the influence of various brands of iron and scrap on the cost of the charge. Preference is to be given to determinations at short intervals,—say quarterly,—rather than longer ones, as changes can then be ordered made in time to effect economies.

(*h*) Smelting materials: All fuel and flux charged into the cupola; fuel recovered from the bed is to be charged again into the cupola. Fuel for other purposes, such as drying ladles, cores, and molds, is to be charged under head *e*.

As the market price of these materials also is apt to vary, and as it is desirable in the analysis to make use of a fixed price, the difference is taken care of by a "market equalizer," as previously explained.

(*k*) Recovered material: This account takes care of all difference between molten iron obtained from the cupola and the salable castings. It is made up of:

1. Equipment: Castings for foundry use, such as weights, flasks, chills, etc.

2. Upkeep: Castings made to repair or replace wastage of foundry equipment.

3. Gates: Gates, cast core irons and frames, sinking heads, and sprues.

4. Wasters: All defective castings.

All of this material will either be present in the foundry or will be charged into the cupola as scrap. In the latter case it is certainly to be rated only at the same value as purchased scrap. In the first case it is conservative policy to rate the material no higher than scrap, as it is very questionable whether it would bring a higher return if sold.

As the material for producing the items under this head has been entered as a charge, its value should be credited to the total costs in order to give a true net total cost.

(*j*) Light: All charges directly connected with the shop lighting.

It is to be remembered that the divisions as here cited are merely suggestive of underlying ideas and principles; in actual practice a larger number will be used, and many will be divided and subdivided. The labor charge, for instance, should be split up into direct and indirect labor, etc.

In general it will be most convenient to reduce all elements to a basis of cost per 200 pounds, or one-tenth ton, as a compromise that avoids the high figures for output when figured in pounds and yet allows ready reduction to the poundrate generally used in the sale of castings.

In comparing costs at different periods it will not do simply to divide the total cost incurred during a week by the total pounds produced during that week and take the result as a pound cost, to be compared with that of some other period. Every manager knows that the cost per pound rises when the product is small and decreases with an increasing output, and will take this into account when comparing costs. But such allowance is made as a matter of judgment only. Now, judgment is a very good thing, but certainty is still better if it can be made to take the place of judgment; in this particular instance that can be done and quite readily. As an example, say that the fixed general expense charge for a week is $1600; with the output 50 tons, the charge per 200 pounds is then $0.80; but for a doubled output of 100 tons the charge per 200 pounds would be halved to $0.40. These values, plotted as a curve for various rates of output on the horizontal scale, give the diagram *a* (see pages 24 to 28).

Similarly, that other element of fixed cost, fixed salaries, is plotted as diagram *b*.

Fluctuating elements of cost are also so plotted, though from the nature of the case the curves cannot be determined by direct calculation, but must be approximately laid down in accordance with experience and judgment. In this way the diagrams for power (*d*), for miscellaneous materials (*e*), and for labor (*f*) are laid down as decreasing with an increase in production. Pig and other charging metal (*g*) and smelting material (*h*) are laid down as horizontal lines, as these items are not apt to be materially affected by the amount of the output.

All of these curves or lines I term ideal curves. Their total will give an ideal total cost of production, as shown in diagram *i*, by the lower line, per 200 pounds of melted iron. If all the iron melted were turned into salable castings, this lower, or 100 per cent., curve would represent also the cost of salable castings. The other curves give the cost of salable castings for the various ratios of such castings to the total iron melted. These curves are determined as follows: Take the total cost per 200 pounds of melted iron as $3.40, the value of recovered iron as $0.20, the salable castings as 80 per cent. Then

the 160 pounds of salable castings would cost as much to produce as the 200 pounds of iron melted, less the value of the recovered iron; *i. e.*:

| | |
|---|---|
| Cost of melted iron, | $3.40 |
| Value of recovered iron, | 0.20 |
| Cost of the 80 per cent. of salable castings is the balance, | $3.20 |

and 200 pounds of salable castings would cost $\frac{3.20}{0.8} = \$4.00$.

This can also be put as a figure to be added to the cost of the melted iron from the equation

$s = (\frac{1}{p} - 1\ (i - r\ )$, in which

$s$ is increase to be added to cost of melted iron to give cost of salable castings;

$p$ is percentage of salable castings divided by 100;

$i$ is value of melted iron;

$r$ is value of recovered iron.

Considering in illustration values from diagram *i*: The actual cost per 200 pounds of melted iron is $3.73, $3.09 and $3.00 in the three periods shown. According to the ideal curve, the lower one marked 100 per cent., these costs should have been $3.40, $3.07, and $2.90. Running up the first week's cost, the manager finds that of the various items the cost for miscellaneous materials (*c*) was by far the higher as compared with the ideal laid down, and instructed the foreman to cut this. Next week the total is still found too high; following this through shows that miscellaneous material cost has been reduced actually below the ideal, but that the labor element (*f*) went up materially; investigation in the foundry showed that the foreman economized on sand mixtures and facings to such an extent as to apparently increase the cleaning labor; the apparent relation between these two elements of cost should be followed up to see whether it is actual. The best way is by a further subdivision of these two elements for some time. As before stated, the analysis is here carried only far enough to explain the idea; nor must the figures given be considered in any other sense.

The following week the total is still found high as compared with the ideal, but more nearly satisfactory.

Looking further, the manager finds that the cost of the salable castings is $4.41, $4.90, and $3.28 in the respective periods (entered as + points in the diagram), whereas they should have been but $4.00, $4.44, and $3.08, to correspond with the ratios of 80, 60, and 90 per cent. of salable

castings. The very low ratio (60 per cent.) of salable castings in the second week is entirely too poor a showing to pass without comment. Tracing upward, it is found that the smelting cost (*h*) was very low, leading to the inference that economy of fuel had led to the very large amount of wasters; investigation in the foundry bore this out, as too dull iron, consequent on the use of insufficient coke, caused a lot of scrapping.

From what has been said it is apparent that this plan of plotting records and methods of analysis based on comparison with ideal conditions keeps the busy manager up to date in his knowledge of what is actually going on, not only as regards totals, but also in detail, so that he is always in position to find a sore spot and apply a remedy based on certain knowledge, backing up his judgment. The method has the further advantage of showing whether the remedy applied really did result in the cure desired or whether it merely brought about a transfer of the sore to some other place.

Knowledge of the fact of such close analysis being made will keep the foreman and others responsible tuned up to concert pitch. It has, in my experience, immediately on adoption resulted in a decrease in costs; showing the foremen actual figures will avoid much of the bad feeling easily raised with well-meaning men when their results are criticized. Being human, they are more or less inclined to ascribe criticism to prejudice. Under this method of absolute analysis responsibility will be placed where it belongs, and it will be possible to bestow praise judiciously in the proper quarter—the old adage to the contrary notwithstanding; "soft words do butter parsnips" to the decided advantage of the firm.

In enumerating the elements of cost, mention was made of a market equalizer to take into account the fluctuating value of the materials bought; this is brought in as follows: the actual unit value of material used at any time is its average cost price; this may, according to circumstances, be either higher or lower than that due to the current market rate or than the ideal assumed. These actual costs of such material are plotted into the diagrams *g* and *h* with the sign O. The actual total costs as modified by the equalizer are also added on the total diagram *i* with the signs * and ×. Consulting this, it will be seen that a recent purchase of pig and coke at high figures had the effect of raising the cost of the last week's output considerably—from $3.00 to $3.20 per 200 pounds of molten metal and from $3.28 to $3.50 for salable castings. The actual utility of separately considering

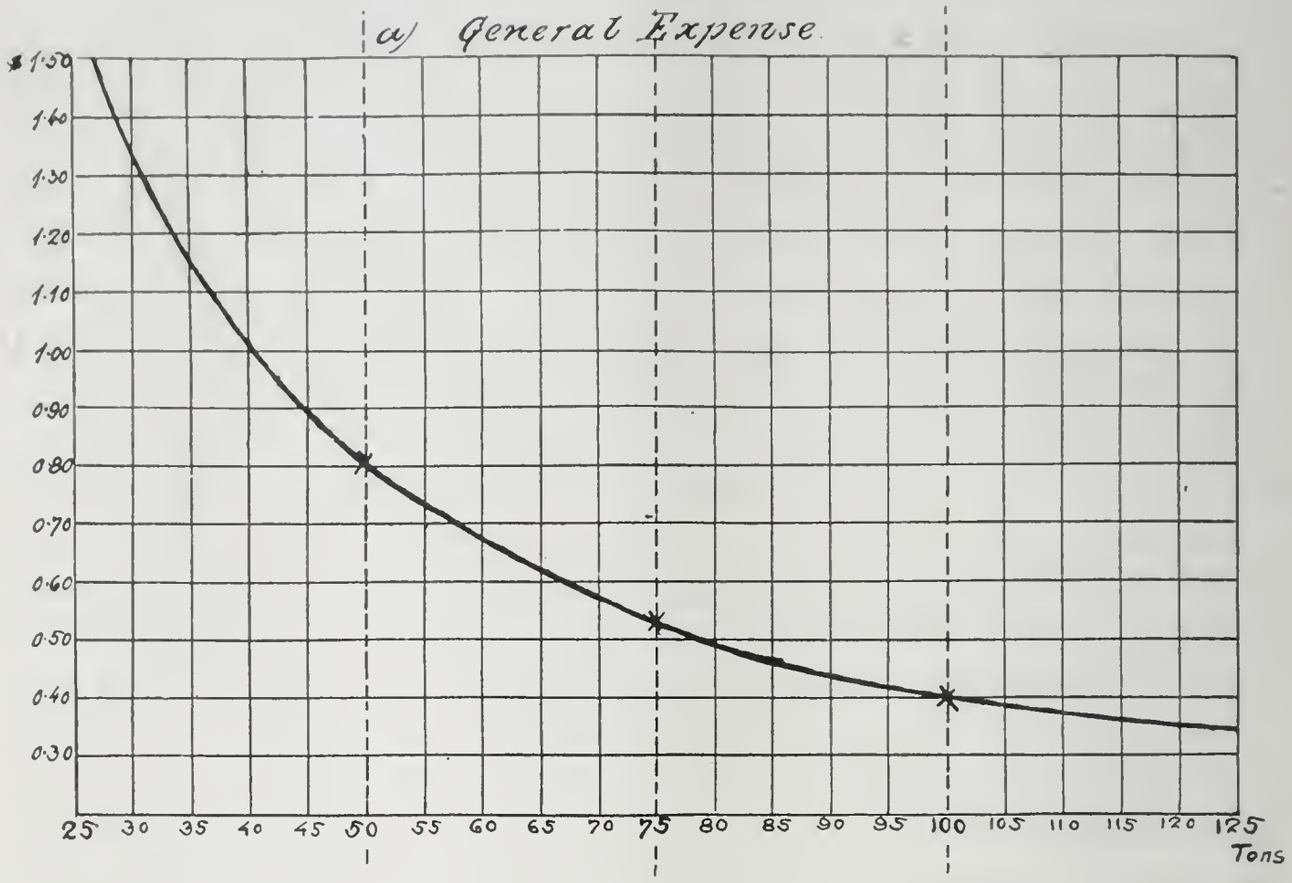
this element is evident, as otherwise the more nearly satisfactory cost of production, so far as under the control of the foundry foreman, would have been obscured. The actual cost due to the market price of the materials being given will allow sales being based on that.

Lighting has not so far been taken into account as an element of cost; this because it is dependent upon the season and the weather, conditions that are not subject to control. This variable character would to a certain extent impair the value and reliability of the main analysis for purposes of cost comparison. I therefore prefer to plot it as an addendum diagram *j*, and to consider its influence on costs separately. In determining sales prices this cost item must, of course, be added.

The totaling diagram, *i*, would be too greatly obscured were curves drawn in for more than each 10 per cent. of variation of salable castings. It is, however, a very simple matter to interpolate points as desired: Say the 95 per cent. line is required at about 60 tons output. Mark the intersection of any vertical in that neighborhood,—say 50 with the 100 per cent. curve,—then the intersection of the next heavy vertical at 10 tons farther along with the 80 per cent. curve; then of the next heavy vertical, at 70 tons with the 60 per cent. curve; now pencil a curve through these intersections. As 95 is midway between 100 and 90, the intersection of the curve just penciled in with the vertical midway between those cutting the 100 and 90 per cent. curves will be a point on the 95 per cent. curve sought. This latter may then be continued both ways approximately parallel to the curves between which it lies.

In conclusion, I may be permitted to point out that this method of cost analysis is not by any means restricted to the foundry, but is applicable advantageously to all lines of work in which the cost of production varies necessarily with some other factor; in most lines of manufacture that factor would be the output. Although rather lengthy to describe, the plan is not at all formidable in actual use. All the data required are assumed as available, being needed for any arrangement of recording costs that may be in use, so that there remains only the work of laying down ideal curves, and of plotting in the actual values; this latter operation is a very simple one that can be quickly mastered by the average costing clerk.

It will give me pleasure to answer any questions as to any point that I may not have expressed myself clearly on, or to go privately more fully into matter that time will not serve to take up here.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1.20
1.10
1.00
0.90
0.80
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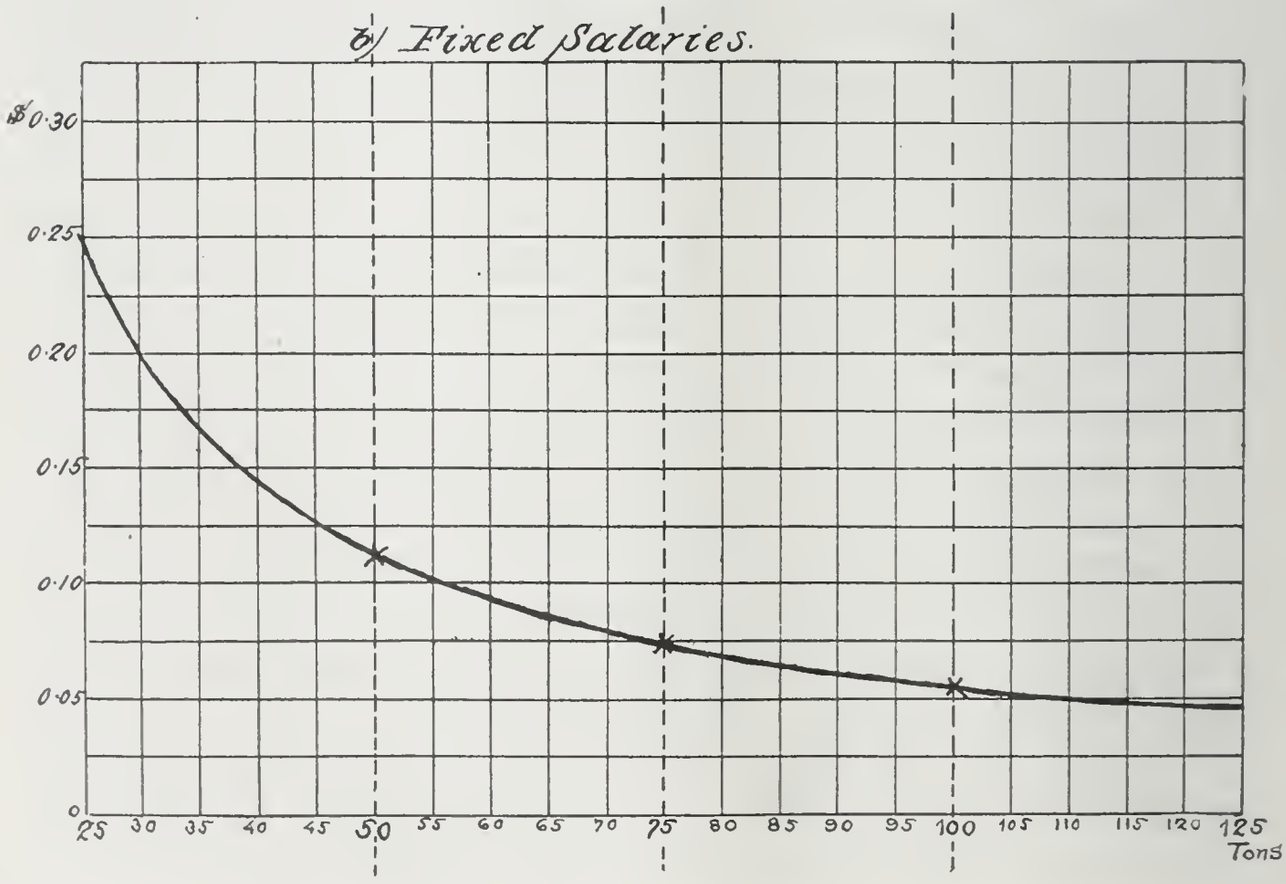
0.50
0.40
0.30
25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
Tons


b) Fixed Salaries.
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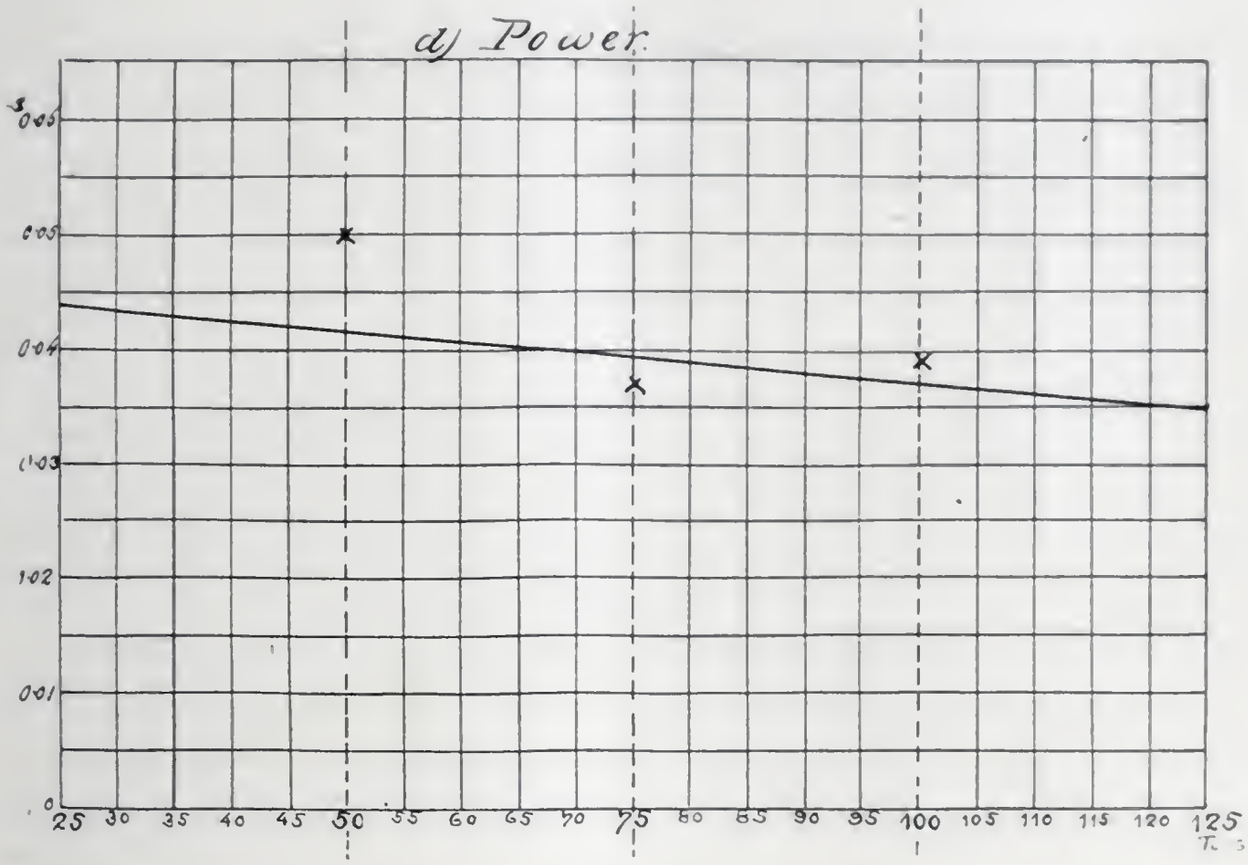
0.20
0.15
0.10
0.05
0
25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
Tons


d) Power.
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0·04
0·03
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0·01
0
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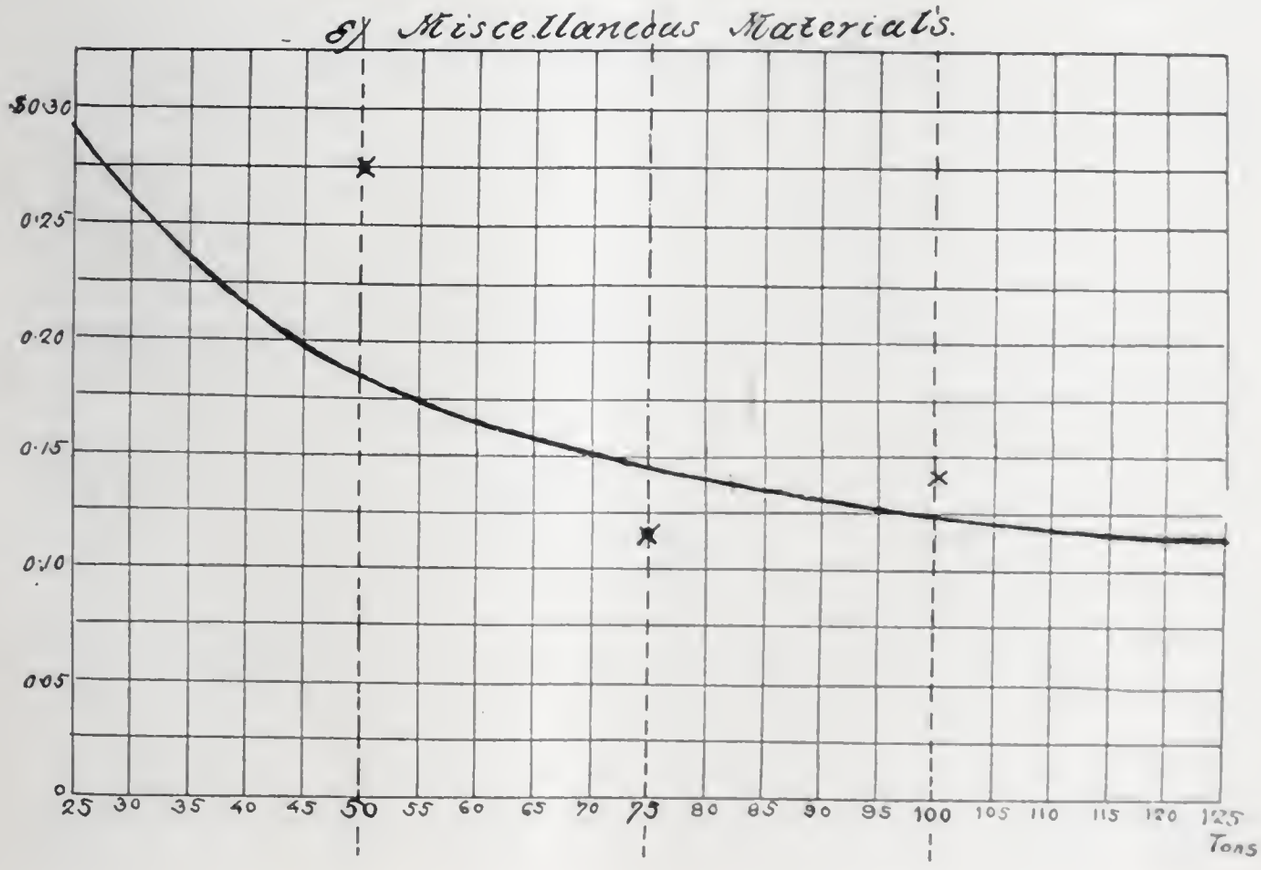
Tons


e) Miscellaneous Materials.
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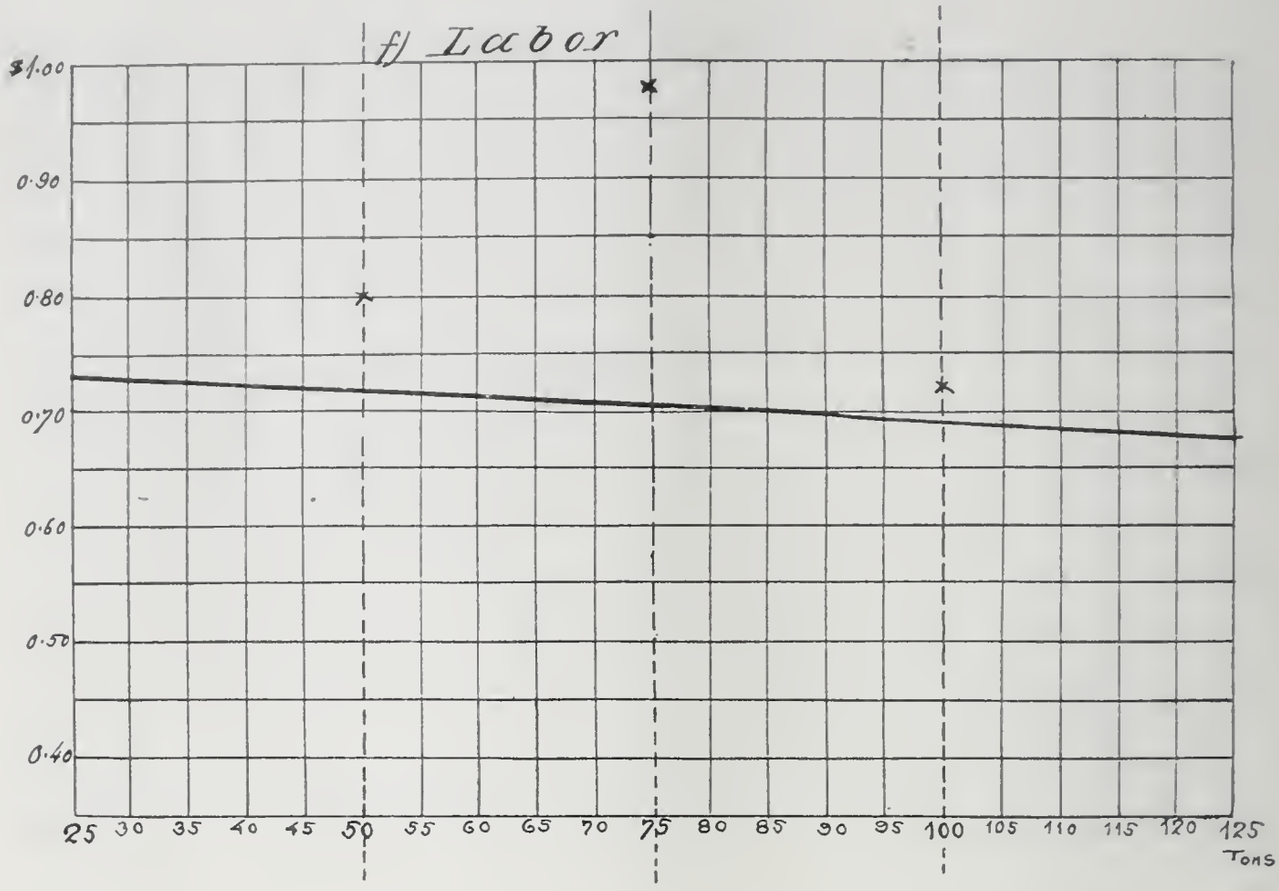
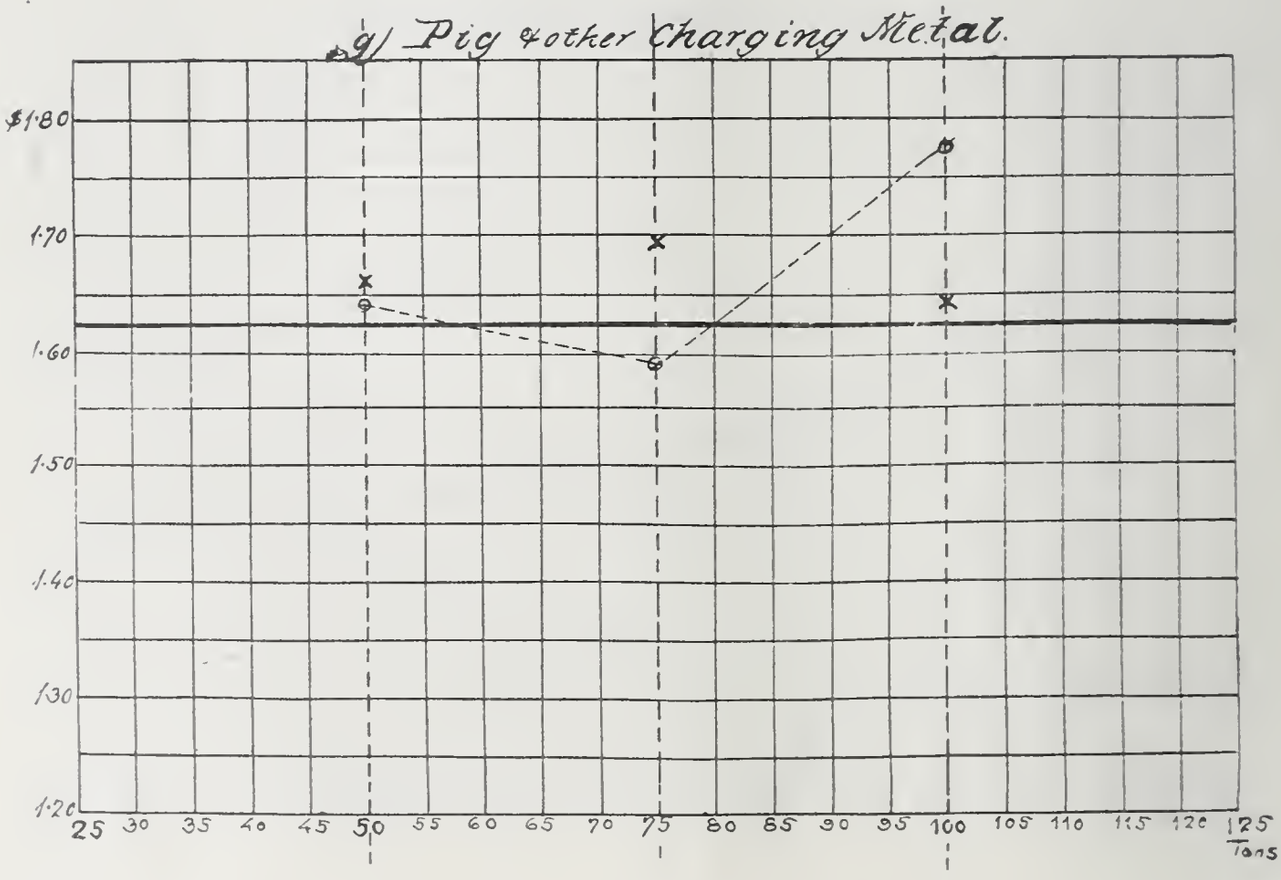
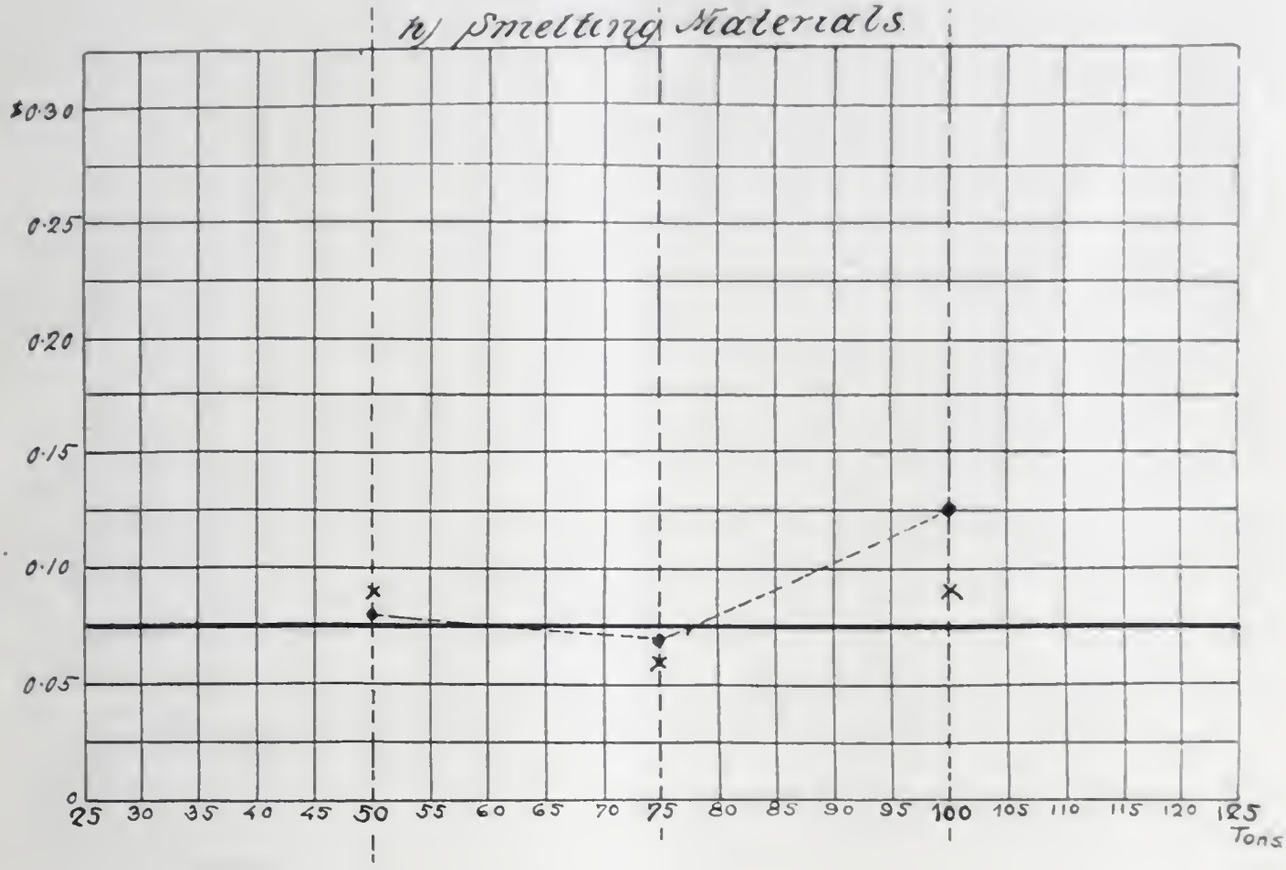
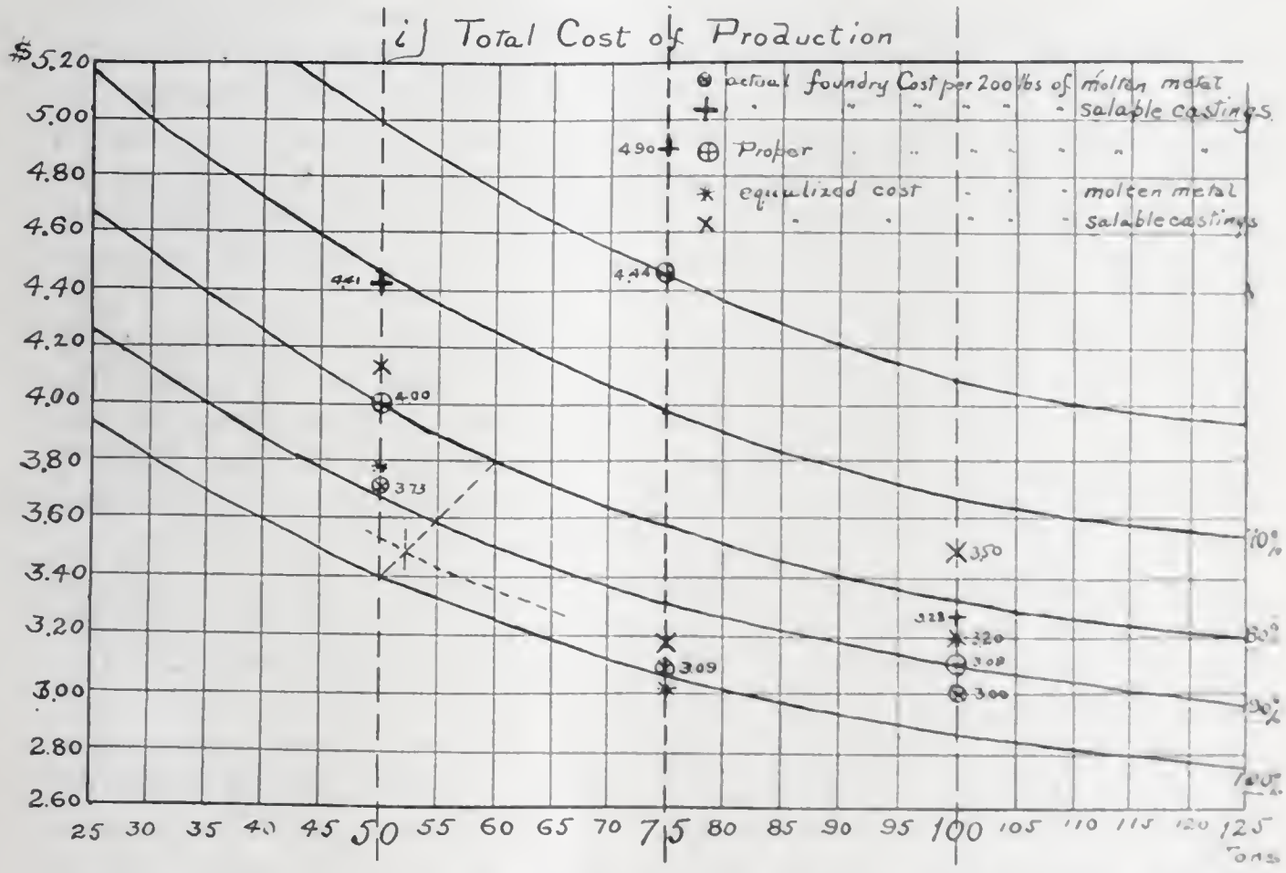
0·20
0·15
0·10
0·05
0
25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
Tons

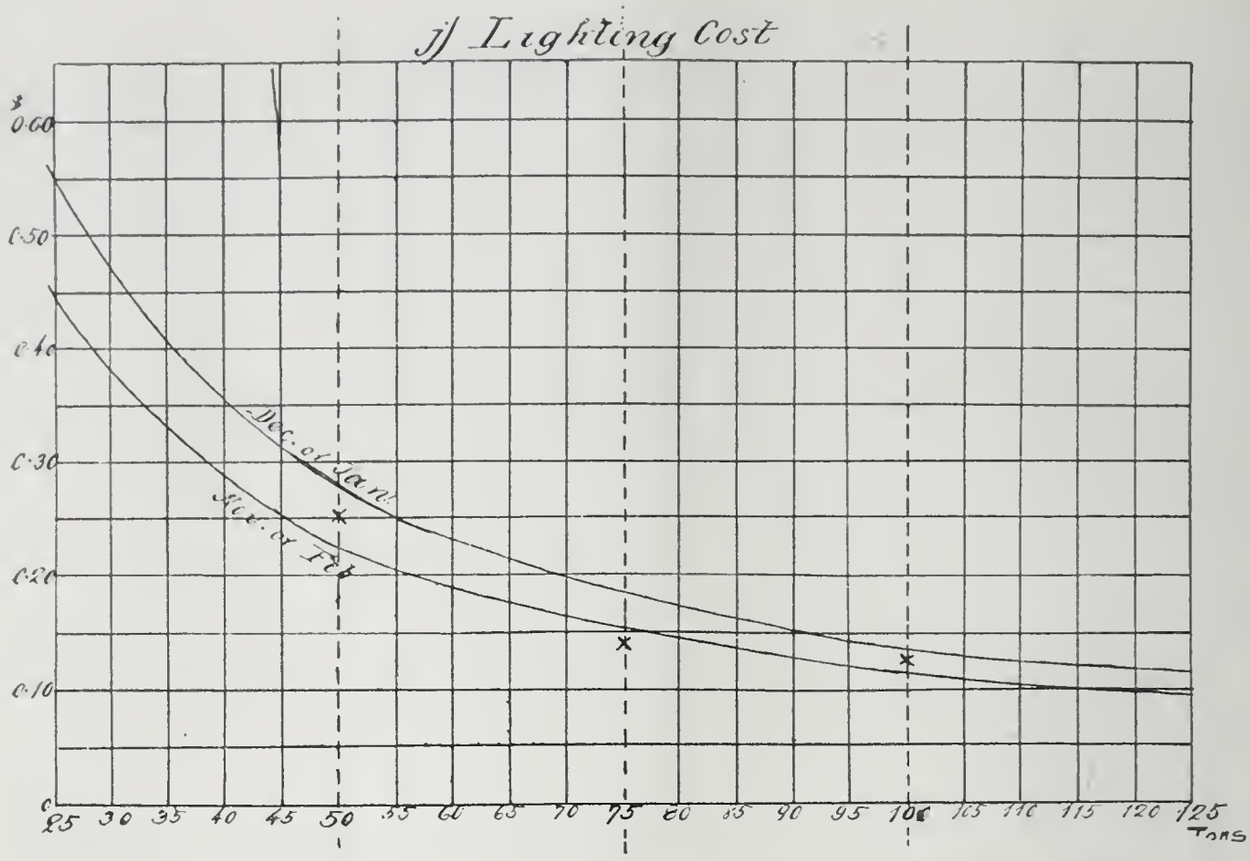

f) Labor
$1.00
0.90
0.80
0.70
0.60
0.50
0.40
25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
Tons


g) Pig & other Charging Metal.
$1.80
1.70
1.60
1.50
1.40
1.30
1.20
25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125
Tons




NOTE.—These diagrams should in practice be so bound together that the dotted lines run continuously over the entire series; that will permit a ready tracing of each period's output to the various elements. Plotting books as used by engineers will be found very useful for entering the diagrams.




## DISCUSSION.

Walter F. Ballinger.—The value of estimating costs I think cannot be too much emphasized. An incident occurs to my mind; a gentleman was telling me a few days ago of a certain firm that failed in business. Something like two years ago this firm (with whom I am well acquainted) asked me if I could get them the privilege of going through the factory of one of their competitors. I said, "Very likely; I'll see"; so I went to a member of the competing firm and asked if there would be any objection to taking one of his competitors through the building. He smiled and said it depends entirely upon who it is. I mentioned the name and he said, "Not for a thousand dollars." He gave as his reason for objecting the fact that this firm did not know how to estimate the cost or value of the work they did. Sometimes they would bid extremely high and sometimes below cost, and his firm would fail to secure work where he knew he was reasonably low, because of the firm that did not know how to estimate. The firm that did not know how to estimate has gone up.

H. D. Hess.—I have been very much interested in the paper this evening. There is one point which I fear is somewhat foreign to the subject, but if Mr. Hess will kindly answer I will be very much obliged. It often occurred to me that it might be desirable to have the costs of castings of different weights and grades kept separate. It is evident that within a foundry's capacity the heavier the individual castings, the greater the output. On light work the production would be cut down. Is it considered, in general, that the cost per pound of castings for the week or month will give a fair estimate of the cost of castings of that average weight, or is it usual to differentiate the costs in order to obtain the costs of heavy castings that are comparatively simple; that is, with little core work, and the costs of light castings, either simple or more complicated?

Mr. Hess.—It cannot be said that there is any generally recognized practice of foundry cost keeping. I think the foundry is less well taken care of in the matter of following costs than any other manufacturing department. I know that in some foundries cost groups are determined by casting weights, in others the amount of core work is the basic factor, on the general assumption that core work costs more for labor. The fact of the matter is that all of these divisions are too broad. If all castings up to five pounds are classed together, then those up to fifty pounds, and so on, and the costs carefully determined most likely castings only five pounds in weight would cost far more in labor than the others. Lumping is not at all fair. It is necessary to get detail cost of individual pieces. That means an amount of work that many foundry managers think totally impossible. As a matter of fact, with a carefully devised system of following costs these may be so collated as to entail almost no extra expense; but such expense, even a quite high one, is justified, as it is almost impossible to overrate an accurate knowledge of all of the detail costs of one's business. It is that which puts one in position to get and to do business at a profit. Usually if the foundry as a whole shows a profit, that is all that is required; under that management a great deal of work will be taken at an absolute and direct loss; but the foundry making the best showing in actual earnings at the end of the year will be that that made a profit on all of its business.

The point to be emphasized is that everything must be considered for itself and then in its relation to other things. If, under the grouping system, the five-pound group were a relatively large portion of the total and the result not satisfactory, investigation should point out the five-pound group as in fault. If then the analysis as laid out does not disclose the cause of the fault, that means that a more detailed analysis is necessary for the five-pound series; such detailed analysis might be kept up later or not, as might be deemed advisable. The fact is that it is almost impossible to lay down any specific rule of universal applicability. No routine that may be laid out will permit dispensing with the element of common sense. It will always be necessary to have a man present who knows what he is after and what he is about. That man should devise the general methods of analysis, so that the detail work may be done by a clerk or inexpensive assistant who will lay the results before his chief, for comparison with the ideal; the chief will follow up differences in whatever way suggests itself as best; that best may be a further subdivision in analysis, or it may be sufficient to go to the shop and find the trouble by a talk with the foreman; detail methods will vary with every man and every foundry.

Messrs. Taylor and Gautt have done much in cost reduction. They have taken certain work and resolved that into the time taken for practically each move made; at first sight a good deal of this sounds ridiculous; but Mr. Taylor was able to cut costs enormously to amounts that were considered totally impossible. Personally I have never applied Mr. Taylor's principles at their extreme, but I can see their wide availability. In the drilling of a novice to careful analysis no doubt the time required is a very serious element; but the trouble and cost will be repaid by the increase of output. All analysis must be made in accordance with the interest of the work in hand and not, as is often the case, simply for its own sake. The thing to be avoided is to have a great deal of work carried along in the head of some one man, and therefore dependent upon his

personality. As quickly as possible everything should be brought down to a basis where it will permit of impersonal study and avoid dependence upon any particular individual; there will always be a field for the resourceful and forceful man without burdening him with duties that merely take up time that he could devote to work that cannot be devolved on others.

E. H. Mumford.—I want to add my word of praise for this paper. I remember that there was a paper read before the Mechanical Engineers' Society some years since on foundry costs, in which the molders' pay-roll was made a basis of estimate and a ratio to fixed charges established with that as a factor. I think the paper (I have forgotten exactly how it went)—I think it advocated taking a previous year's experience of the ratio to fixed charges of the molders' pay-roll as a basis of estimate for the current year's business. A mere contrast with the very broad conception of such a scheme as this of the very nicely detailed conception of Mr. Hess's, shows how much closer he is getting to the real question. It seems to me that to handle the subject of costs in the full detail that Mr. Hess does shows us the difficulty of this problem of estimating foundry costs. Instead of attempting to establish any broad ratio, Mr. Hess studies each detail by itself. Probably in the same way the thoroughly experienced and competent foundry foreman gets at the subject. He has in his head, from his long experience, each detail that Mr. Hess, for the benefit of all of us, has put on paper, so that he can apply to his particular work, without thinking very much about it, the various curves which he has in his head and get at the result which anybody not so equipped could not get at; and it seems to me that Mr. Hess's paper will furnish a good many of us with tools to use in estimating foundry costs. I remember, when I had charge of a large foundry, receiving a letter from a New York club, from the proprietor of the foundry, saying he thought I had too many non-producers, reminding me that the only man in the foundry who made money for his employer was the molder. He had discovered that I had two carpenters, and wanted to know what a carpenter had to do with an iron foundry. It is quite easy to suppose carpenters are important items of expense if a casting, say, of a large bed plate, is to be bedded in the floor. Even the lumber used would come into play and perhaps the Teamsters' Union. The practical estimator would take those things into account at sight, but the very first week of an experience of that sort would show a discrepancy from Mr. Hess's curves, which would then be looked up and traced to the making of big wooden cope flasks. It seems to me that Mr. Hess's paper is valuable in pointing out the enormous rambling detail of foundry expenses, and the easy way he has found for systematically keeping track of them.

Mr. Hess.—I may say that I was forced into this idea of analyzing costs on the basis of variation in output. At the time I had under my charge a rather large establishment—the German Niles Tool Works of Berlin, Germany—and unfortunately by the time we were ready to put our product on the market the bottom had dropped out of business generally. In attendance on the decreasing output our costs were going up continually; every foreman and subforeman placed the blame on the outputs going down all the time. We all know that is a good excuse; but the costs were increasing faster than seemed to me justified by the decrease in output. In laying down my "ideal curves," I called in the so-called "foundry engineer" (in Germany every man must have a title, and

his was "foundry engineer"). At the end of the very next period the costs were found to have decreased in despite of a decreased output, and that without having carried through the analysis in detail of any one item. The mere fact that there was a figure based in output to which the "foundry engineer" would be strictly held,—and not only he, but all others,—operated to have all costs and times checked much more closely and to bring about a reduction of total costs; so that an arrangement of this sort has a twofold value—that of so fixing and locating responsibility that each man knows there is no crawling out of it, and then after that element of irresponsibility is eliminated, of showing just where advantageous changes should and can be brought about.

# NOTES ON THE CONSTRUCTION OF AN ELECTRIC ROAD AND POWER-HOUSE AT MORGANTOWN, WEST VIRGINIA.

WALTER LORING WEBB.

*Read November 7, 1903.*

THE construction of electric railroads has now become so common that a detailed description of every item of construction would be a waste of time. But the circumstances under which the road at Morgantown was constructed are in some respects so unusual that a description of them seemed justifiable. It is thought that they will form a fitting introduction to a topical discussion of the general subject of electric roads.

Morgantown is situated in the northern part of West Virginia but a few miles south of the Pennsylvania line. It is on the Monongahela River about 100 miles above Pittsburg. The elevation of the river at this point is a little over 800 feet above tide, or, let us say, above the outlet at the Gulf of Mexico, 1500 miles away. A half-mile back from the river the hills rise almost as much again. On a ridge a few miles out of Morgantown there is a stretch of road which is so unusual that it rejoices in the name of "the mile ground." It is so nearly level that for about a mile it is actually possible for a horseman to speed his horse safely. This does not mean that the road is actually level—it is only comparatively so. These statements have been made to illustrate briefly the fact that Morgantown is in a very hilly country—that the grades on streets and country roads are very excessive—that the usual limits of grade and the usual power requirements per car per mile of road must be thrown away and the problem attacked on an independent basis.

Laying out a route for an electric road is usually only a question of procuring the most business—assuming that there is a blanket franchise and no trouble regarding right of way. But in Morgantown the question of grade had an influence which made certain routes absolutely impracticable and which called out much study to deter-

mine the advisability of lesser grades. The topographical features make it somewhat of a "shoe-string" town—long, narrow, and strung-out—the very best kind of a town to furnish business. It is the seat of the State University, which claims an enrollment of nearly a thousand students. The location of some of the University buildings is sketched on the map. There are several large glass factories and other mills located there. These furnished the justification for the location of the line along the river road. Here the line

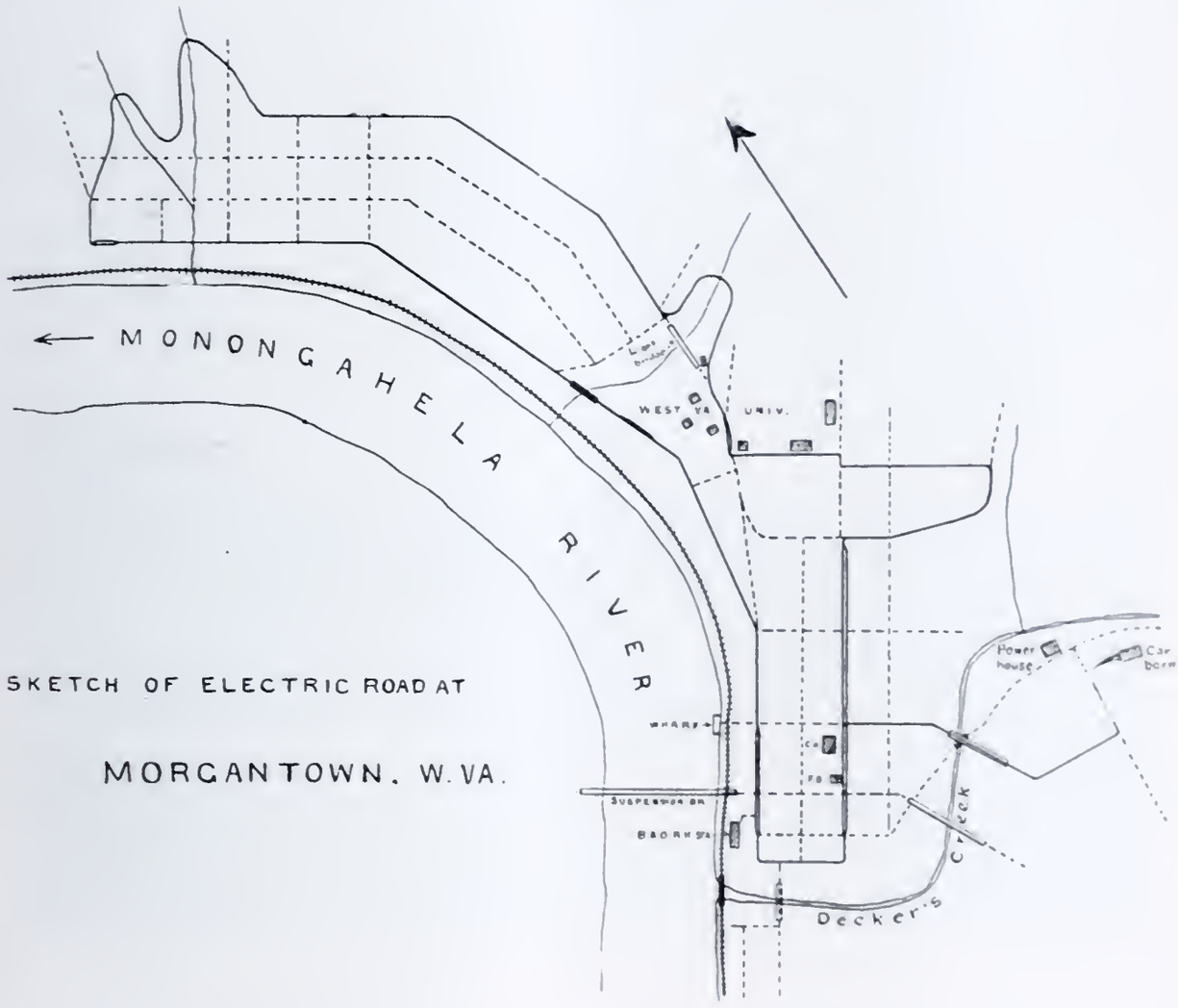



Fig. 1.

was comparatively level, the highest grade being a little less than 8 per cent. The side hill above this stretch was so very steep that the people living very far from the line could not be expected to walk very far up and down that grade to take a car, and so another line at a higher level was decided to be necessary. The lower street was a very important one and deserved to have a line on it, and it was impracticable and undesirable to attempt to catch all the traffic

by a single line part way up the hill. Then, too, it was desired to run the cars past the University buildings and through Main Street (about a hundred feet higher than the river). The lower line passed as near as practicable to the Baltimore and Ohio Railroad station. The extension of the line to the north-east was decided on partly because a more direct route met with objections from property-owners and partly because it is intended to extend the line out one of the country roads that runs out that way. Incidentally considerable traffic is picked up, while the operation of the road is not unduly burdened by the detour.

Fig. 2.—From Summit, Looking South.

The result of all this is a single track loop line about three and a half miles in length with two long sections of double track and other passing switches which enable cars to run in both directions and thus give to all parts of the town a high degree of service considering the number of cars operated. The double tracks (which, with the sidings, increased the mileage to four miles) were inserted largely with reference to the suburban extensions, which were surveyed but which have not yet been constructed. Considerable opposition was developed when it became known that we intended to double-

track nearly the whole of Main Street. I defended it by calling it an extra long "siding." When threatened with trouble by the City Council, I demonstrated to them that the double track was put there to prevent congestion of traffic—so that the tardiness of a suburban car would not disarrange the schedule of the city cars nor block traffic—that with a double track the cars would be always moving—that even if any waiting for cars became necessary, it could be done at the ends of the double track, which are outside of the business section. A sufficient number of the opposition became convinced of the advantage to the public of the double track and it was formally authorized.

The switches were first laid out on the basis of a six-car schedule, three cars running each way constantly. The road was started with two or three cars before the loop was complete, but as soon as completed, the superintendent made up a four-car schedule and operated it on that plan. This necessitated a long quick section followed immediately by a short lazy section. It would have been still worse except for the double track. But we found that by putting in one extra siding we could (thanks to our double track) operate a perfect four-car or six-car schedule. During our arguments with the City Council about the double track one of our directors brought up an argument which is very interesting and somewhat novel. The width between curbs on Main Street is such that a truck, being loaded or unloaded with its back to the curb, would obstruct a car running along the middle of the street, but would not obstruct a car on the farther track of a double track. Therefore if the track were in the middle of the street, such a truck would obstruct cars running in either direction, while with a double track it would obstruct only the cars running on the near track. Therefore, whatever the schedule, a double track would allow teams twice as much time to unload as the same cars on a single track.

*Track.*—A large part of the line has been paved with a brick pavement. The method universally used there is to lay the brick on a thin layer of sand which is spread directly on the subsoil. Fortunately the soil is so firm that this makes a fair pavement as long as it is not disturbed, but after a few trenches have been dug for water, sewer, and gas pipes, the surface of the pavement is about what might be expected from such a method. Considering the nature of the pavement, a concrete foundation for the track was a useless refinement, but I determined to put down a good foundation.

After digging to the proper depth, the subsoil was rolled if necessary. The specifications called for rolling, but throughout a large part of the line the soil appeared so firm at a depth of seventeen inches that I allowed the rolling to be omitted. Four inches of broken stone were then laid. The ties and rails were then laid and surfaced and tamped with ballast until the total thickness of ballast under the ties was about six inches. In the paved portion the ballast was filled up to about an inch above the top of the ties. Then a cushion coat of sand was laid, on which to set the paving brick. As we had some difficulty in obtaining a sufficient supply of broken stone for

Fig. 3.—From Summit, Looking West.

ballast, we used gravel for the tamping ballast. This gravel is dredged from the river at Pittsburg; it is of course thoroughly washed, and makes a very good ballast for tamping. It cost us about 70 cents in the track, while the broken stone cost us about $1.25. This method of track foundation proved very satisfactory. Subsoil drainage proved advisable in a few low places. The rails used were seven-inch "Shanghai" rails. That height of rails was necessary on account of the brick pavement, and the use of such rails prevented trackage by teams on the rails.

*Poles.*—We used juniper poles on the line work. Juniper seems to be nearly if not quite as good as cedar, and very much cheaper than cedar can be bought now. We paid $4.31 for 35-foot poles, 7 inches at top; and $6.13 for 40-foot poles, 7 inches at top. These prices were f. o. b. Morgantown. They may seem high, but Morgantown suffers from high freight rates for materials purchased elsewhere and high prices for materials procurable in that region. Considering the very high quality of the poles, these prices were low compared with the prices demanded for other kinds.

*Rolling Stock.*—The rolling stock called for in the initial order

Fig. 4.—Working Down the Side Hill.

included six 10-bench open cars, with Brill's 21-E trucks and six 18-foot box cars with the same trucks. These were equipped with General Electric No. 67 motors and B-23 controllers. This order, as first made up and approved by the company, called for seven box cars and six open cars, the seventh car being included so that when running a six-car schedule there would be one extra car to allow for the disability of one car. This order was actually sent in, but it was afterward modified when it had occurred to one of the directors that thirteen cars was an inauspicious number for the first order.

The only special feature of the rolling stock is the magnetic brake, and as this is perhaps not well known to all of you, a brief description is justifiable. On each side of the car, midway between the rails, is swung a powerful electro-magnet. These magnets normally hang about one-quarter inch above the rails and are beveled at the ends so that there is no danger of their catching on the track. They are operated from the controller, which is somewhat modified for the purpose. When it is desired to use them, the controller is turned to zero, thus throwing off the line current. Then turning the con-

Fig. 5.—A Crooked Line.

troller past zero, the motors begin to act as dynamos and magnetize the magnets. The faster the cars are moving, the more powerful will be the action. It should be noted that these brakes act directly on the rails, in spite of their being slippery or even icy; that with them there is no necessity or excuse for flat wheels; that they will work even if the trolley jumps off and there is no line current; they require no great exertion from the motorman; they consume power which otherwise goes to waste or which is spent in grinding up wheel tires and brake shoes; they do not take power from the line, as is

done with the pneumatic brake. The power of all wheel brakes is absolutely limited by the possible retarding action of the friction of the wheels on a rail which is perhaps very slippery. While there is, of course, a limit to the power that can be developed by these magnetic brakes, it is very much greater than the wheel brake. Finally, the brakes for the closed cars are so connected that the current runs through the electric heaters, and so the heating of the cars in winter comes from the waste energy and not as an additional drain on the line current. These brakes cost $200 each for the open cars and $290 for the closed cars where they had the heating attachment.

*Trolley Wire.*—4/0 trolley wire was used throughout. The location of the power-house is quite central, and will be still more so when the proposed extensions are built. The arrangement made it possible to make the feed-wires very short and the use of 4/0 wire made the maximum drop in voltage very small. This was still further helped by using a double trolley wire on the short stretch of single track connecting the double tracks on Main and Front Streets. Incidentally this eliminated the line switches and enabled the cars running in each direction to use their own wires from one end of the double track district to the other.

## Power-house.

*Location.*—The location was decided on partly from mere business and real estate considerations, but chiefly on account of its central location with respect to the territory to be served, which so influenced the feed-wire problem. Another consideration was the stream and the mill dam. When I first arrived in town, the amount of water in the stream was very great, owing to recent rains, and the possibility of utilizing the water-power, as the mill had previously done, was somewhat alluring. But it was soon demonstrated that although the power was ample at times, it was so variable and unreliable that no dependence could be placed on it. But then I concluded that I could at least utilize the dam as a storage reservoir for our water-supply. Even this purpose was foiled. Although the dam was a very old one and had successfully withstood many a flood, a comparatively moderate flood started a scour around one end of the dam. The scouring quickly developed until a large channel was made around the end and the foundations of the power-house were endangered. It was quickly decided to sacrifice the dam. It had been built of cribwork, tied with iron rods, and filled with stone. Some

dynamite was inserted and it was hoped that one or two charges would open up a channel which would divert the water from the ends But some of those oak timbers were as solid as when they were placed, and it required many charges, as well as the removal by hand of the stone filling, to thoroughly clear the channel. The stone taken out was used to make a rock-fill wing wall at the side where the scour occurred, which will, I think, effectually prevent the repetition of any such scouring action. Another feature, which made us decide that the dam was useless and should be removed, was the fact that some coke ovens had just been started up-stream, and we knew that in a short time the stream would be so fouled with sulphuric acid that it would be unfit for boiler use. The condition of the dam was such, after the flood, that a considerable expenditure would have been required to put it in order, and therefore the safest plan was to remove it and obviate the danger of further damage by flood. The illustration* shows the remarkable bank of solid unseamed rock that forms the opposite bank of the stream. A short distance above the power-house bed-rock cropped out at the surface. It was therefore assumed that a rock foundation could be obtained with but little excavation, and that it might even be necessary to excavate into the rock at places in order to put the building at the desired elevation. But apparently the stream had in times past scoured out a much deeper channel which had again filled up, and so after digging down until it seemed hopeless to get rock within a reasonable depth, the foundations were made of concrete on a firm gravelly soil. At the time I left there had been no evidence of settlement.

*Building.*—The fundamental structural idea of the building was a brick wall, stiffened with brick buttresses and supporting a fireproof roof having steel trusses. The brick buttresses not only relieved the architectural plainness of many such structures, but it permitted a reduction in the thickness of the walls between the buttresses which resulted in a much stronger building considering the volume of brick-work. Of course the trusses and the travelling crane are supported on the walls at the buttress points. The contractor complained that the projection of these buttresses complicated the structure of the scaffolding and thus added to the cost of the work, but I do not think that any such added cost was more than the gain.

*Generators.*—It is a commentary on the power demanded by the

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* Shown as a lantern slide

grades of that line that a 200-K. W. 600-volt railway generator was found to be necessary to run six cars. And since it is confidently expected that the line there installed is but the nucleus of a much larger system, two such generators, each direct-connected to a 325-H. P. vertical compound Westinghouse engine, were bought. The power-house was designed for the ultimate placing of four such engines. The first work of the company, after organization, was to buy up the existing electric light plant, a corporation whose chief value lay

Fig. 6.—Power-house.

in its franchise. Its equipment and wiring were antiquated and were already very greatly overtaxed. But the business already on hand and the business that could be counted on as soon as facilities were offered seemed to justify the immediate installation of two 180-K. W. alternators, two-phase, 2200 volts, running at 7200 alternations. These were each belt-connected to 275-H. P. vertical compound Westinghouse engines, by 21-inch belts with a span of 24 feet. Space for another such installation was also made in the design of the power-house. By the time an additional installation is required it may be that steam turbines will have so demonstrated their

economy that even greater power can be developed in the space now vacant.

*Boilers.*—The boilers selected and immediately installed were three Stirling boilers, each of 310 nominal H. P. These have been designed for a working pressure of 180 pounds, although the plant is now operated at about 135 pounds. Although Morgantown is situated in the heart of the region where the best of the Pittsburg and Freeport bituminous coals are at their best and cheapest, natural gas is even cheaper. And so, although these furnaces have been equipped with grates so that a coal fire can be started up on a few moments' notice if the supply of gas should suddenly fail, they are also equipped with Kirkwood burners for burning the natural gas. This gas comes to the building under a pressure of 120 to 150 pounds per square inch and passes through a reducing valve which reduces the pressure to a few ounces. An automatic governor keeps this pressure constant at the firebox. A very slight adjustment of this governor by the fireman is sufficient to produce any desired change in the steam pressure. This sensitiveness was very forcibly illustrated to me by a fireman who changed the governor very slightly, and almost instantly the pressure, as shown by the gauge, was seen to increase. Restoring the governor to its former position, the pressure again became normal. The fireroom is designed for three more such boilers—enough to handle engines of more than 2000 H. P. The feed water for the boilers is heated by a feed-water heater of 1200 H. P. The question of using condensers was studied, and it was decided that they were not justifiable. The natural gas used by such large consumers is sold for five cents per thousand. In this case, however, the company holds leases on thousands of acres of gas lands, and therefore paying the gas bill is simply a matter of book-keeping. But even allowing the actual expense in cash of the cost as charged to similar consumers, the cost of heat there is so small that such saving as might result would not pay the interest and depreciation on the plant required. The engine-room and also the car-barn will be heated from the exhaust steam, and it was considered that this use, together with the feed-water heater and the compounding in the engines, represented as much saving as is worth while out of 135-pound steam.

*Draft.*—The power-house was designed for an immediate installation of 1200 H. P. with space for a subsequent installation of about 1000 H. P. additional. Plans and estimates were made for a brick stack for immediate necessities and also for one for future require-

ments. Of course, these had to be designed on the basis of burning coal, since natural gas cannot be depended on indefinitely. A small stack would cost considerable and might have to be duplicated in a very few years. The larger stack would cost much less per horsepower, but its full capacity might not be needed for many years, and in any case it meant an immediate and large expenditure. Also either plan called for a stack much larger than the immediate requirements for burning natural gas necessitated. The plan adopted enabled us to "eat our cake and keep it too." A steel stack was

Fig. 7.—A Sharp Corner—Change in Grade 13 Per. Cent.

erected which is 7 feet in diameter and whose top is 50 feet above the boiler-room floor. This is large enough to furnish an adequate natural draft for the three boilers burning natural gas. The system is provided with a 10-foot fan and engine built by the Sturtevant Company, which will provide induced draft whenever necessary. The plans were also made on the basis of the installation of another fan connecting with the same stack when the three other boilers are placed. The cost of this installation was far less than that of an adequate stack; the fan and engine need not be used at present, but

it is there, all ready for use on very short notice; and the makers declare that the single fan and stack now placed could develop sufficient draft for 2000 H. P. if forced. Even the additional steam which will be required for the fan, when it becomes necessary to use it regularly, will be cheaply purchased considering the very low price of fuel. This is another illustration of how the price of fuel there (which is so abnormally low) has a marked influence on the economics of plant installation and justifies an additional use of steam to save immediate outlay, just as in the case of the condensers it was cheaper to waste some of the energy of the steam rather than increase the outlay in order to save it.

## DISCUSSION.

The President.—Mr. Webb's very interesting paper is before you for discussion, gentlemen.

James Christie.—As I understand Mr. Webb, the steep grade he refers to terminates at a curve, which is a bad combination. What are the inclination of the descent and the radius of the curve at its foot? Grades of this character are uncommon in this vicinity, although we have a few, approximating 10 per cent., in the Roxborough roads. These, however, are quite short and are not associated with curves. On Leverington Avenue there is quite a long ascent, of six to eight per cent., terminating at a curve, and several accidents have occurred here by reason of the car acquiring a dangerous velocity in the long descent and leaving the track as it entered the curve. The magnetic rail brake which Mr. Webb has referred to affords increased means of safety.

Mr. Webb.—I will say in regard to that grade that the conditions there were such that it could not be prevented. The grade of twelve per cent. occurs only where we are passing through an existing street. I tried to avoid it by running a line which should make a loop, but I found that although I could make a loop which would have a less average grade I could not avoid a steep maximum grade. It would have required a steep grade in some one place, in addition to introducing a great deal of curvature. The length of that steep grade is about five hundred feet. At the bottom it necessarily turns the corner into the Main Street, and that again is unavoidable. The curve at the bottom was a standard 90 degree curve, with a spiral at each end, and the case that I was speaking of, where the car ran away, was at this place. Whether the motorman acted right or not I cannot say. The statement was made that the wheels were turning backward when he reached the bottom of the grade. This, of course, must mean that he had reversed the current, and since he was running with a reversed current of course it means he was not using the rail brake. I think it would have been more effective if he had used the rail brake, but I do not pretend to know. As a matter of fact, the car was going down at a very high rate of speed and ran around that sharp curve without being derailed. It was claimed that one reason was the fact that the wheels were

turning backward. If they had been turning forward or had been stationary, the car wheels would probably have climbed up over the flange; but the wheels turning around backward for some reason kept them on the track. Of course, that curve is double guarded. There is another thing that makes trouble with those very sharp curves: All those cars are four-wheel cars with seven feet wheel-base, and that means that on those curves of thirty-five feet radius the angle made by the wheel flange and the rail is very great, very much greater than it is with double truck car wheels on which the wheel-base is very much shorter.

Wm. Easby, Jr.—I would like to ask if any emergency tests of those brakes were made?

Mr. Webb.—We have made none there. I don't know what has been done elsewhere. There is one peculiarity about the action of those brakes to which a motorman called my attention. We were running down a rather steep grade on the road, and at the top of that grade, going at a fair speed, he turned off the current and threw the controller past the zero point; that is up one or two notches on this brake contrivance. We were going so slowly then (half speed) that the brake had no appreciable effect, and we kept on going downhill and increased our speed. He said "Just notice; I won't touch this." At the bottom of that grade was a street corner where he was required to slow up, and yet without touching that controller, when he got down near the bottom of that grade we began to get such a high speed that suddenly the brake began to work automatically; the car was brought down to a very slow speed when we reached that street. It did not work until we were moving at that high speed and then it reduced to the proper speed for crossing that street. In regard to the remark that the brakes act so suddenly, that is entirely due to the motorman. I have learned, while riding on those cars, that it is possible, if a motorman knows how to work those brakes, to make them act in an ideal way. They need not act suddenly, but just in the way I have described. The motorman can make them work almost automatically. There is one objection, and one which I should suppose it would be an easy matter to remedy, and that is that when the car is going up a steep grade, and it is desired to stop, say at a street crossing, then the motorman must use the hand brake to hold the car, because in going up the grade the car is going so slowly that even if the current is turned off and run past the zero point so as to apply the brake, not sufficient magnetic force will be developed to hold the car, and it will at once run backward down the grade. That does not endanger the safety of the car, as by the use of the handbrake it is easy to hold it.

Rollin A. Whittick.—I would like to ask Mr. Webb whether he can give a fuller description of the details of the power-house—the roof structure, flooring, in and outside repair shop, and as to the repair bins, etc.

Mr. Webb.—The structure of the power-house was made fire-proof as much as possible. The roof was covered with Ludovici tile laid on light steel angle irons which rested on jack purlins. Again, on the roof, there were five lines of trusses, about fifteen feet apart. The walls, as you saw by the illustrations, were brick. The floor was concrete. The engine-room and boiler-room were separated by a fire-wall in which there was only one very small door, so that in the event of a fire in the boiler-room (which of itself was rather improbable

because there was very little there to catch fire) it could hardly communicate to the engine-room. Of course, all possible precautions were taken to avoid the chance of fire, owing to electrical leakage.

Mr. Whittick.—I presume the same construction was used in the car barn?

Mr. Webb.—Substantially, yes; except that the roof of the car barn was not made fireproof. In the case of the car barn—at least in the shed part, where the cars would be—there was nothing below the roof to catch except the cars.

Mr. Whittick.—The roof was planked?

Mr. Webb.—Plank covered with slate.

Mr. Whittick.—Is Mr. Webb at liberty to give us the probable cost of construction per mile, exclusive of rolling stock,—the cost of rails, construction, and overhead work?

Mr. Webb.—Possibly I might be at liberty to do so, but I have not the figures here, except in a very approximate way—what I can remember of it. The contract price for the track work—for track laying, excavating, restoring the road-bed to its original condition—was, I think, eighty-five cents a linear foot, reduced down to seventy-two cents a linear foot out on the suburban part, where there was no paving to be taken care of. The materials were all furnished—that is, the rails, ties, ballast, sand to go under the paving brick, and special paving brick where desired. I said we used a Shanghai rail. I also designed a special brick which was made in Morgantown (brick-making is one of the industries there), which, nominally at least, had the same effect as though we had a grooved rail; that is, the brick was so formed that, extending underneath the head of the rail, it came up alongside the head so as to form a groove, such as would be made by a grooved rail. I say, nominally it would do so. I am sorry to say that, like all such things, since the brick was laid on sand it did not require a very heavy truck going over it to move it just enough so that, instead of having a little narrow groove, it soon developed to be a pretty big one.

Mr. Whittick.—There is just one more question regarding the electric brake. Is it possible to bring the car to a full stop on a down grade with that brake? We use a brake something of that kind, but it is impossible to come to a full stop. The car commences to glide as soon as the magnets become demagnetized. The car will not drift?

Mr. Webb.—No.

Edward S. Hutchinson.—Can Mr. Webb tell us the cost per mile issued from the rolling stock and power-house, for about four miles rough estimate?

Mr. Webb.—I am afraid I can hardly give it even roughly.

Mr. Hutchinson.—Including everything.

Mr. Webb.—I have not got the figures ready. I will mention one reason why the whole financial outlay to the Company seems very large. For one thing, you will notice that the power-house was designed for a large ultimate installation—about two thousand horse power. In the next place we installed immediately, including the lighting engines, about twelve hundred horse power. A large part of the expenditure was for electric light wiring, as well as the trolley work, and I believe that the Company spent altogether somewhere between two and three hundred thousand dollars. Of course, it would be ridiculous

to say that three or four miles of road would cost two or three hundred thousand dollars.

MR. HUTCHINSON.—Was the electric light for the benefit of the city or just for their own use?

MR. WEBB.—For the city. I made the statement in the first part of the paper that the Company bought the electric light franchise for lighting the city.

MR. WHITTICK.—I understand the cars were run in both directions. Was any system of signals used automatically?

MR. WEBB.—No; I tried to get adopted a system, substantially that used on the West Chester line and some other lines around the city, but it was not thought to be necessary.

# PROPORTIONS OF REGENERATIVE GAS FURNACES, WITH SPECIAL REFERENCE TO OPEN-HEARTH FURNACES.*

H. D. HESS.

*Read December 5, 1903.*

In 1860 the first actual fusion of cast-steel was effected in a reverberatory furnace, but it was not until a few years later that the introduction of the regenerative furnace made possible the production of open-hearth steel. The importance of this material is shown in the fact that its production in the United States has grown from 893 gross tons in 1867 to 4,656,309 gross tons in 1901, this being more than half the Bessemer steel made in this country during that year. In the same year Great Britain produced 3,297,791 gross tons of open-hearth steel.

Regenerative furnaces possess the following distinctive advantages:

I. Production of high temperatures.
II. Use of lean gases.
III. Economic use of fuel.
IV. Admirable control of furnace.

Firing a preheated fuel promotes complete combustion and high temperatures; this is so to a still greater extent when both air and gas are preheated, as in the use of producer gas in regenerative furnaces. Although exceedingly lean, ordinary producer gas makes a satisfactory fuel for regenerative furnaces when both air and gas are preheated. The regenerators absorb and use heat that would otherwise pass to the stack and be lost. In burning fuel as a gas, the least excess of air is required for complete combustion, leading to great economy. Through the system of air and gas valves, the furnaceman has absolute control of the working of his furnace.

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* The treatment of regenerative furnaces presented in this paper is based largely upon Toldt's "Regenerativ-Gasöfen," edition of 1898. Among other books which have been freely consulted are: Ledebur's "Handbuch der Eisenhüttenkunde," edition of 1899–1900; Campbell's "Manufacture and Properties of Iron and Steel," edition of 1903; Davis's "Manufacture of Bricks, Tiles, and Terra Cotta," edition of 1889.

Figure 1 is a plan of flues and regenerators. Figure 2 shows a section of a furnace, illustrating regenerators, hearth, etc. Figure 3 is a gas or air reversing valve.

The most common fuel for regenerative furnaces is producer gas.

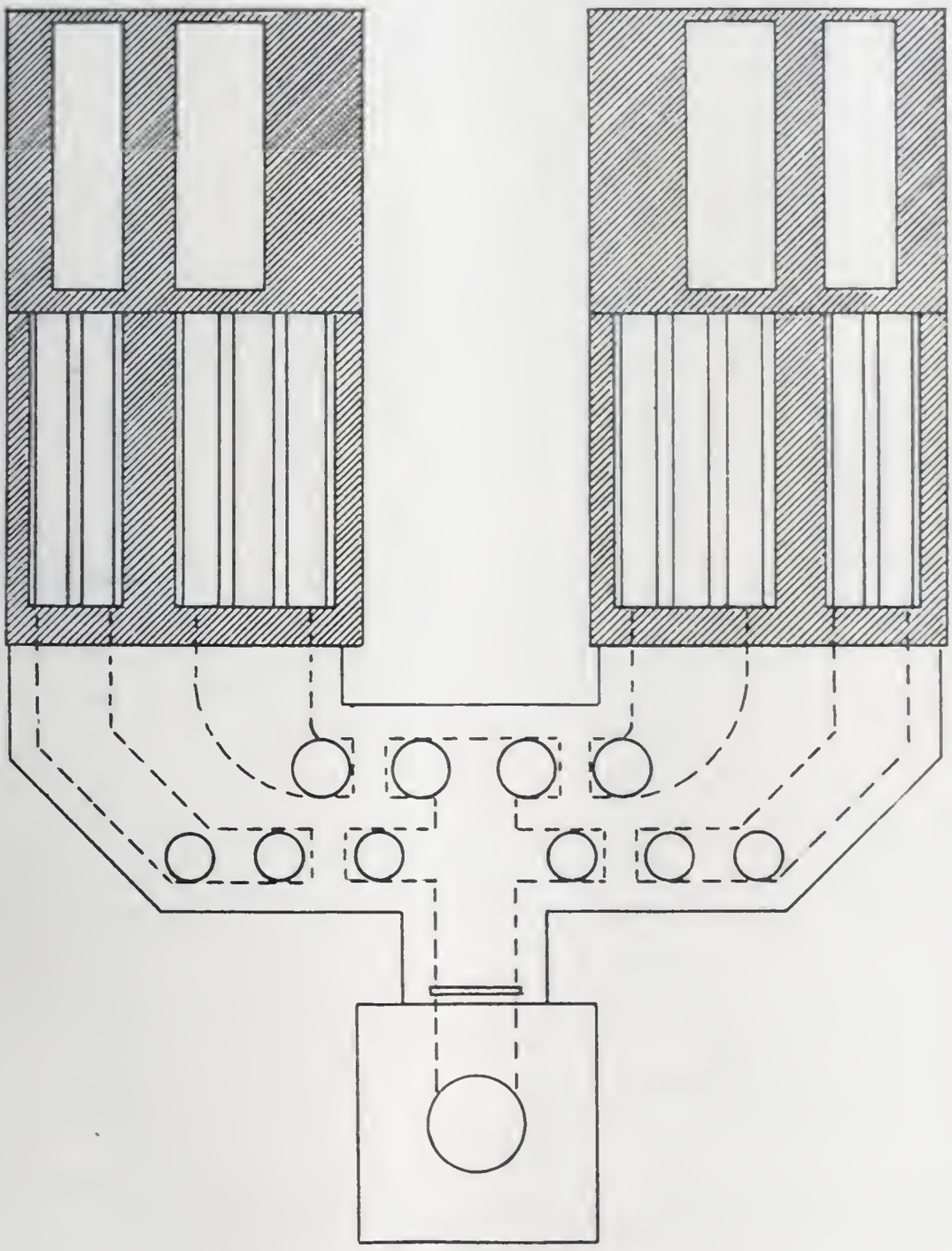

Fig. 1.—Plan of Flues and Regenerators.

This is generated by the incomplete combustion of coal, the air required for combustion being driven through the bed of fuel by a steam-blower.

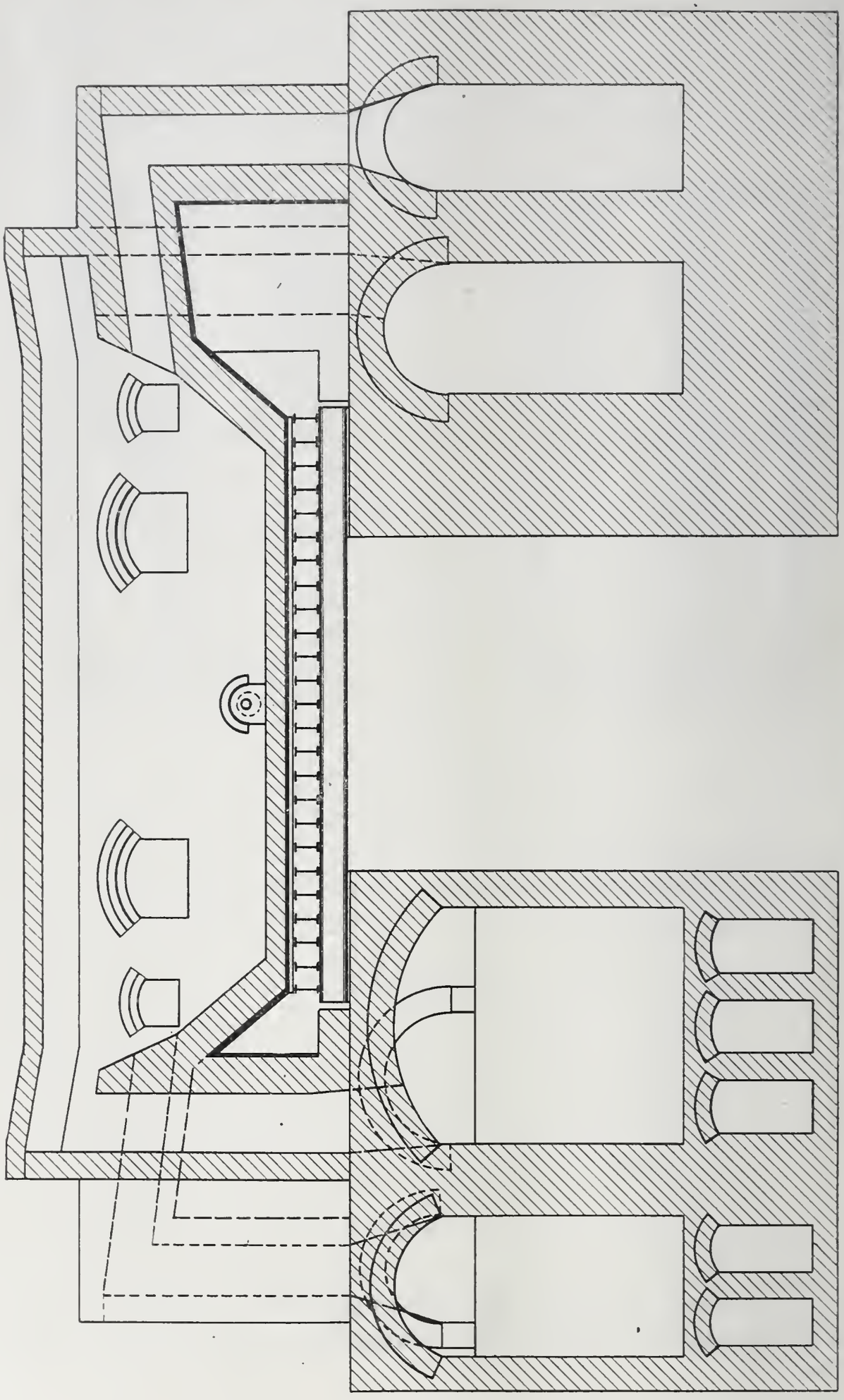

Fig. 2.—Section through Furnace, Showing Hearth, Regenerators, Flues, and Cinder Pockets.

Below are 3 analyses of producer gases by volume:

| | No. 1. | No. 2. | No. 3. |
|---|---|---|---|
| $CO$, | 27.1 | 27.0 | 22.0 |
| $O$, | — | 0.5 | 0.4 |
| $CH_4$, | 4.1 | 3.2 | 3.2 |
| $H$, | 7.6 | 12.5 | 10.5 |
| $CO_2$, | 3.8 | 3.0 | 5.7 |
| $N$, | 57.4 | 53.8 | 58.2 |

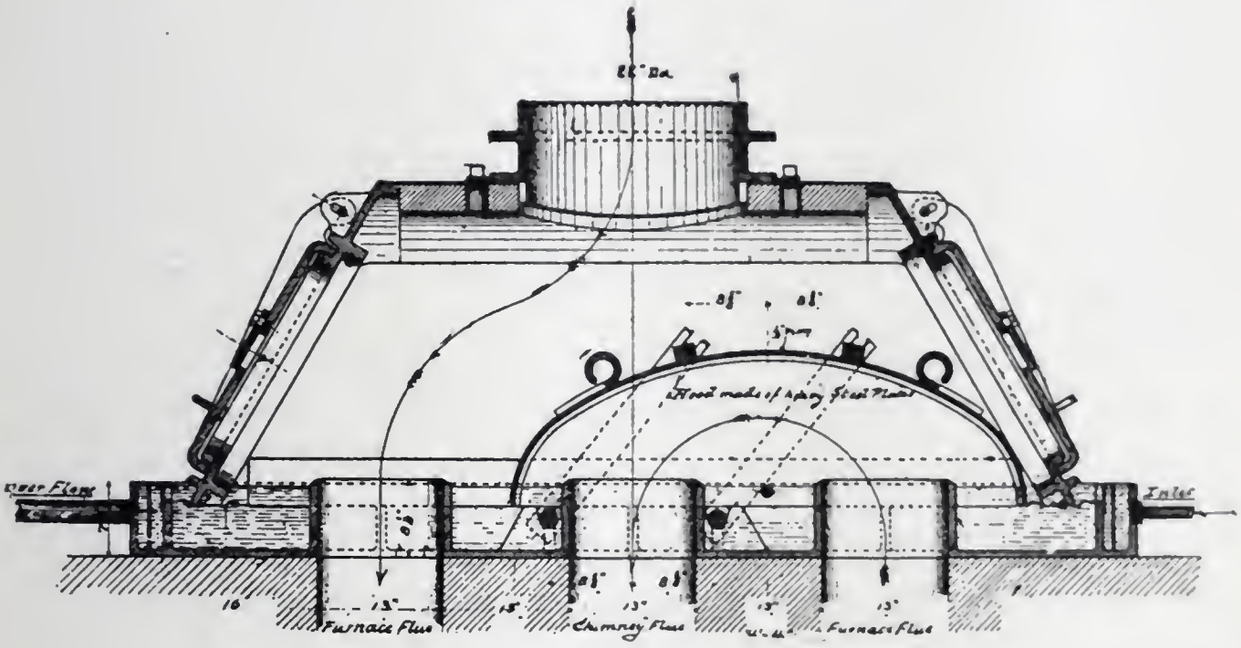


Fig. 3.—Air or Gas Reversing Valve.

Producer gas has a calorific power of about 150 B.T.U.'s per cubic foot, about one-sixth that of natural gas. The coal generally used for producer gas approximates the following composition:

| | |
|---|---|
| Volatile matter, | 36.5 % |
| Fixed carbon, | 56.0 % |
| Moisture, | 1.5 % |
| Ash, | 6.0 % |
| Sulphur, | 1.1 % |

One ton (2240 pounds) will generate from 150,000 to 160,000 cubic feet of gas at ordinary pressure and temperature. Ledebur states that in order to have a uniform action over the entire area of the producer, the inside diameter rarely exceeds 5 feet. In American practice inside diameters of 8 feet 6 inches with 10-foot shells are quite common. He states that when a chimney draft is used for the producers 14 to 19 pounds of coal can be burned per hour, and that with a steam blower three times this can be consumed. In American practice with

hand-poked fires and steam blowers a consumption of 15 pounds of coal per hour can be estimated on, while with mechanical poked producers 30 to 35 pounds can be gassified per hour.

The cross-section of outlet from the generator, tubes, or sewers leading gas to the regulating valve should, according to Toldt, permit a velocity in the gas of 1 m. per second with the gas at 300° C. In American practice the gas will be nearer 650° C., but it can have a correspondingly higher velocity. These requirements correspond to a free area of $\frac{6}{10}$ square foot for each 100 pounds of coal burned in the producer or producers per hour. The producers are set in batteries with either lined overhead tubes or underground sewers leading the gas to the regulating valves. In either case ample provision is made for cleaning; in the case of sewers this largely influences the proportions, as they should be made for access so that they can be cleaned when burning out is not satisfactory.

The gas of analysis given required about 55 cubic feet of air per 1 pound of coal for its generation; without steam or moisture in the air 73½ cubic feet would have been required. Theoretically the coal would require 144 cubic feet of air for complete combustion. Coal burned under a boiler uses at least 25 to 50 per cent. excess of air, so it is seen that the same amount of air from a compounded steam blower of the usual type should burn about three times the weight of coal in a producer that it would under a boiler.

Although tests of gas producers usually show a pressure under the grates of less than 1 inch, the blower should be able to furnish the required air with a back pressure of at least 2 inches of water. The basis of calculation for furnaces is the fuel consumption per hour. For convenience in open-hearth and reheating furnaces, the coal at the producers will be taken rather than gas delivered to the furnaces. An estimate of the probable coal consumption for any furnace can only be satisfactorily based upon knowledge of the fuel consumption of a similar furnace working under corresponding conditions. The producer being the usual type with steam-jet blower, 100 pounds of ordinary bituminous gas-coal will produce 7000 cubic feet of producer gas at 0° C. and 760 mm. atmospheric pressure.

*Stack.*—The quantity of gases drawn through a stack varies directly with the section. The maximum discharge occurs with a mean stack temperature of 522° F. The effective head increases more rapidly at first than it does later on with increased height, so that stacks should rarely exceed 100 feet to 130 feet in height. The important point to

decide is the inside area of the stack. The burning of 100 pounds of coal in the producer will give 36,500 cubic feet of stack gases at 760 mm. pressure and 522° F., the gas burning with 20 per cent. excess of air.

Both Toldt and Ledebur recommend an average velocity of the stack gases of about 16½ feet per second. This would require $\frac{8}{10}$ of 1 square foot for each 100 pounds of coal burned per hour. If the gases are hotter, the volume will be greater; but the permissible velocity will also be greater. A stack section of $\frac{9}{10}$ square foot for each 100 pounds of coal burned at the producers per hour would correspond to a velocity of 11 feet per second in the stack gases.

COMPARISON OF STACKS OF SEVERAL FURNACES.

| Size of Furnace. | Estimated Coal Consumption: Pounds per Hour. | Inside Diameter. | | Stack Area. | Square Feet per 100 Pounds per Hour. |
|---|---|---|---|---|---|
| | | Ft. | Ins. | | |
| 10 ton O. H. furnace ..... | 800 | 3 | 6 | 9.6 | 1.20 |
| 30 " " " ..... | 1900 | 4 | 6 | 15.9 | 0.84 |
| 50 " " " ..... | 2900 | 6 | 0 | 28.3 | 0.98 |
| 50 " " " ..... | 2900 | 6 | 2 | 29.8 | 1.05 |
| 35 " " " ..... | 2400 | 4 | 8 | 17.1 | 0.71 |

The average of ten furnaces of which the above are samples was about 0.95 square foot for each 100 pounds of coal used per hour. It must be mentioned, however, that the 35-ton furnace was one noted in the "Iron Age" for November 5, 1903, and had the remarkable product of 642 tons per week.

Figure 4 shows the temperatures of the gas, air, and products of combustion passing through a furnace as given by Toldt and Le Chatelier. The temperatures assumed are indicated by the lines III and VI, and are believed to come more nearly to general practice; for instance, Toldt gives the average temperature of gas leaving the producers at 300° C., Le Chatelier 720° C., and Campbell 655° C. It seems probable that this temperature is much nearer 750° C. than 300° C.; 650° C. has therefore been assumed as this temperature. The fall in temperature of the gas in passing from the producers to the gas valves will largely depend on the nature of the conduits, whether sewers or overhead tubes; if tubes, whether lined or not; and in any case upon the distance transferred.

It is further assumed that the gas and air shall leave the regenerators at about the same temperature, 1200° C. While this is contrary

to the recommendations of Toldt and others, who state that the air should enter the furnace hotter than the gas so as to assist mixing and combustion, it is difficult, considering the high velocities at which

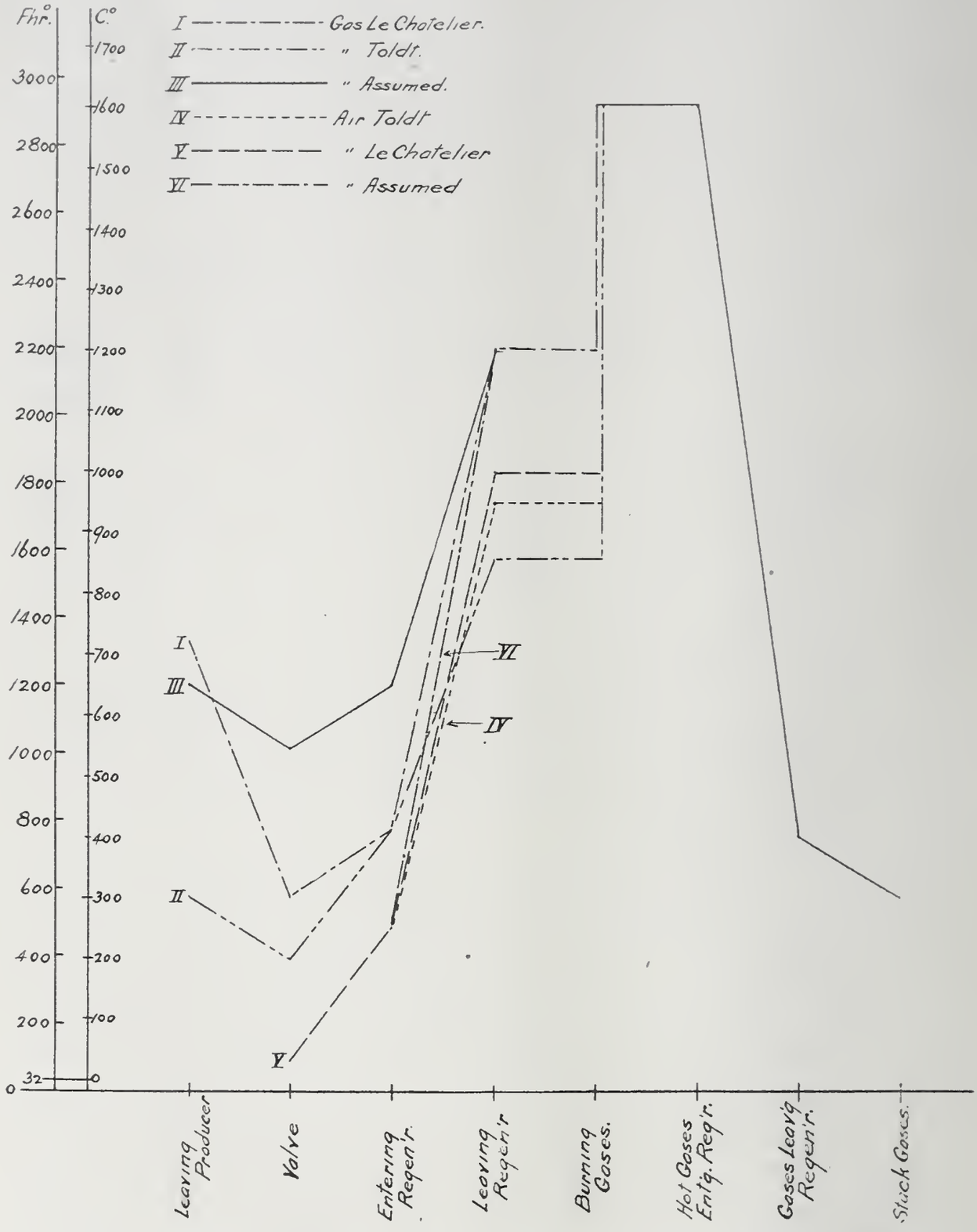


Fig. 4.—Temperatures of Air and Gas passing through an O. H. Furnace.

both air and gas enter the furnace, to see how any slight difference in density can assist in mixing them; further, considering the more

usual regenerator ratios, it is doubtful if they can impart a higher temperature to the air than to the gas.

*Air and Gas Valves and Flues between Stack and Furnace.*—All masonry flues should be made of ample proportions, as they assist the regenerators, and a low velocity of the gases facilitates their alternately receiving and giving up heat. In addition to this, the frictional resistance of masonry flues greatly exceeds that of metal tubes and valves. Flues are liable to fill with soot, which reduces their effective area. On the other hand, it is desirable to maintain a higher velocity through metal valves, permitting them to be smaller, and in the case of water-sealed valves the gas will take up less moisture than if a greater area was exposed to contact with the water. In order that the gas and air may both take up as much heat as possible in these flues, Toldt recommends a velocity not exceeding 5 feet per second. These flues are usually enlarged at the furnace to the size of the flues under the regenerators. The producer gas from 100 pounds of coal burning with 20 per cent. excess of air will require about 10,200 cubic feet of air at 760 mm. pressure and 0° C. If the 100 pounds of coal are burned in an hour, the air passing through the air flue per second at 86° F. would be 3.14 cubic feet. Toldt recommends a velocity through the air and gas reversing valves of from 3 to 5 m. per second (9.8 to 16.4 feet). As the air is usually dependent entirely on the pull from the stack and regenerator flues to the furnace, the velocity through it should not exceed 10 feet. This would require an air valve opening of 0.31 square foot for each 100 pounds of coal burned per hour at the producers, which is one-third the stack area where the stack is allowed $\frac{9}{10}$ square foot for each 100 pounds of coal burned at the producers, while the flue section is two-thirds the stack section.

COMPARISON OF AIR AND GAS VALVES OF SEVERAL FURNACES.

| Size of Furnace. | Coal Tons per Hour. | Air Valve. | | Air Flue. | | Gas Valve. | | Gas Flue. | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 10 ton furnace .... | 800 | 3.1 | .39 | 4.7 | .59 | 3.1 | .39 | 4.7 | .59 |
| 30 " " .... | 1900 | 7.1 | .37 | 14.1 | .75 | 4.9 | .26 | 12.8 | .67 |
| 35 " " .... | 2400 | 6.0 | .25 | | | 4.9 | .20 | | |
| 50 " " .... | 2900 | 12.6 | .43 | 22.3 | .76 | 9.6 | .33 | 19.7 | .68 |
| 50 " " .... | 2700 | 8.4 | .31 | 16.8 | .62 | 7.1 | .26 | 15.4 | .57 |
| Average..... | | | .37 | | .68 | | .29 | | .65 |

Column marked 1 gives square feet of section.

Column marked 2 gives square feet of section per 100 pounds of coal per hour.

It will be noticed that these averages for air valves and flues agree very closely with the sizes recommended by Toldt. The gas enters the gas valve under pressure from the producers; in addition, it has practically the same pull through the furnace that the air has; the velocity of the gas can therefore be much higher through the valves than the air. Toldt gives a velocity of 3 to 5 meters (9.8 to 16.4 feet) per second. This, however, is based on gas at 200° C. and on not using a steam blower at the producers. Considering gas at 550° C. delivered to the gas valve under pressure, a velocity of 7 meters (22.96 feet) per second would not seem excessive. Under these latter conditions the 7000 cubic feet of gas resulting from 100 pounds of coal per hour would require a gas valve section of 0.26 square foot. As there will be very little transfer of heat to the gases in the flue between the gas valve and the regenerators, a velocity of 3½ meters (11.5 feet) will not be too high.

This makes the combined area of 1 air and 1 gas flue 1.2 times the area of the stack opening, and 1 air and 1 gas valve three-fifths the stack area. Since the velocity of the stack gases is 11 feet per second, the velocity of the burned gases passing through 1 gas and 1 air valve will be about 22 feet per second, which will not be too great. The flue leading from the air and gas valves to the stack is really a continuation of the stack, and should about equal it in area. It is quite commonly made from one-half to three-fourths of this area.

## Regenerators.

There is probably no portion of a furnace at which there is greater diversity of sizes than at the regenerators.

The general requirements of regenerators are as follows:

1. Ample cross-section, so that the air and gases may have a low velocity, giving them sufficient time for heat transference. A high velocity will also carry more dirt and dust into the regenerators; this chokes the passages and prevents transfer of heat. Toldt suggests a velocity of 1 m. (3.28 feet) for air and gases in lower regenerator flue, 2 m. (6.56 feet) through checkers, and ½ m. (1.64 feet) in upper regenerator flue.

Toldt says that the ratio of air to gas regenerator should be such that the final temperature of the gas will be somewhat lower than the air, producing a denser gas, a longer flame, and a better distribution of heat in the furnace. This depends somewhat on the size of the furnace, the smaller furnaces working better on hot gas. American designs do not seem intended to meet this requirement.

3. Regenerators should have excessive rather than small capacity. With too small a regenerator the gases pass to the stack red-hot, resulting in a high fuel consumption. The objections to large regenerators are:

(*a*) Excessive first cost.

(*b*) Troublesome renewal of checker brick.

4. The design should permit the air and gases to use the entire contents of the chambers; *i. e.*, no short path through regenerators.

The mean specific heats of gases determined by Mallard and Le Chatelier for 1 cubic m. of the gas between 0° C. and t° C. is:

$$\begin{aligned} CO, O, H \text{ and } N &= 0.306 + 0.000027\ t. \\ CO_2 &= 0.374 + 0.00027\ t. \\ CH_4 &= 0.418 + 0.00024\ t. \end{aligned}$$

The ratio of heat required to raise 1 volume of gas from 650° C. to 1200° C. to that required to raise 1.45 volumes of air (the quantity required by 1 volume of producer gas burning with 20 per cent. excess of air) from 270° C. to 1200° C. is:

$$\frac{1 \quad \times .388 \times 550}{1.45 \times .346 \times 930} = \frac{5}{11}$$

This should compare with the regenerator volumes.

In practice this regenerator ratio varies from two-thirds to three-fourths, but the tendency is to reduce the gas and enlarge the air chamber. In working hot gas this ratio should be between one-half and two-thirds.

The following regenerator capacities are recommended by several authorities.

Grüner states that the weight of one gas and one air chamber should be 50 kgs. of tile for each 1 kg. of coal burned between any two reversals, and states that it is customary to use 60 kgs. per 1 kg. per hour. He further states that he found regenerators to vary from 0.04–0.07 m. per 1 kg. per hour. [59 to 103 cubic feet per 100 pounds of coal per hour.]

Siemens estimated that the checkers in one air and one gas chamber should weigh sixteen or seventeen times as much as the fuel burned between reversals. It will be noticed that this represents about one-fourth the amount recommended by Grüner.

Ledebur considers that in practice 1 air and 1 gas regenerator has a contents of 4.0 to 8.0 cubic m. for each 100 kgs. of coal burned per hour. [65 to 130 cubic feet per 100 pounds of coal per hour.]

Campbell states that the contents of one air and one gas regenerator should be at least 50 cubic feet per ton of metal in the furnace, while double this amount is better.

All the above are probably based on one-half the chambers being voids.

REGENERATOR CAPACITIES.

| Size of Furnace. | Pounds of Coal Burned per Hour. | Checker Contents 1 Air and 1 Gas Chamber. | Ratio Air Gas Chamber. | Contents 1 Air and 1 Gas Chamber. | |
|---|---|---|---|---|---|
| | | | | Per 100 Pounds Coal per Hour. | Per 1 Ton Furnace Capacity. |
| 10 ton O. H. furnace..... | 800 | 774 | 1 | 97 | 77 |
| 30 " " " ..... | 1800 | 936 | 1.4 | 52 | 31 |
| 30 " " " ..... | 1800 | 1423 | 1.1 | 79 | 47 |
| 50 " " " ..... | 2700 | 2760 | | 102 | 55 |
| 50 " " " ..... | 2700 | 1980 | | 73 | 40 |
| 45 " " " ..... | 2430 | 2520 | 1.66 | 103 | 58 |
| 40 " " " (acid) | 2320 | 2600 | | 112 | 65 |

Campbell states that in the 50-ton Steelton furnace the contents of one air and one gas chamber are 100 cubic foot per ton of furnace capacity. These volumes do not include the space occupied by the flues beneath and above the checkers.

Omitting the furnace with the smallest regenerator, the average contents of one gas and one air chamber are found to be 94 cubic feet for each 100 pounds of coal burned per hour, or approximately 1 cubic foot per 1 pound of coal per hour. The voids are between 50 and 60 per cent. The average contents per 1 ton of furnace capacity is about 57 cubic feet.

The several dimensions of the chambers will to an extent depend on the location and design of the furnace. According to Toldt, the horizontal section should be selected so that the mean velocity of the air and gas should not exceed 6 feet per second, 10 feet per second in the flues under the regenerator, and $1\frac{1}{2}$ feet per second in the upper portion of the regenerator. The 10,200 cubic feet of air required for each 100 pounds of coal burned at the producers would at the mean regenerator temperature of 725° C. require a total horizontal regenerator section of 7.0 square feet; the vertical section of the air flue under the regenerator would be 0.57 square foot. The 7000 cubic feet of gas from 100 pounds of coal at the mean regenerator temperature of

925° C. would demand a total horizontal regenerator section of 2.87 square feet and a vertical lower flue section of 0.66 square foot.

Allowing a velocity of 10 feet in the upper regenerator flues would necessitate a vertical section in the air flue of 1.53 square feet, and in the gas flue of 1.05 square feet for each 100 pounds of coal used per hour. The 1½ feet recommended by Toldt would necessitate flues entirely too large.

AIR AND GAS REGENERATOR FLUES.

Sections per 100 Pounds of Coal per Hour.

| Size of Furnace. | Fuel Used per Hour Pounds. | Air Regenerator. | | | Gas Regenerator. | | |
|---|---|---|---|---|---|---|---|
| | | Horizontal Section. | Vertical Section. | | Horizontal Section. | Vertical Section. | |
| | | | Lower Flue. | Upper Flue. | | Lower Flue. | Upper Flue. |
| 30 ton furnace .... | 1800 | 4.65 | 0.8 | 1.4 | 3.3 | 0.53 | 1.0 |
| 50 " " .... | 2700 | 8.20 | 0.8 | 1.2 | 5.0 | 0.55 | 0.7 |
| 50 " " .... | 2700 | 7.30 | 0.7 | 0.7 | 4.8 | 0.48 | 0.48 |
| 45 " " .... | 2430 | 7.4 | 1.16 | 1.23 | 4.5 | 0.68 | 0.82 |
| Average ..... | | 6.9 | 0.88 | 1.13 | 4.4 | 0.56 | 0.74 |
| Calculated ... | | 7.0 | 0.57 | 1.53 | 2.9 | 0.66 | 1.05 |

The gas chamber's horizontal section, upper and lower flues are usually controlled by the ratio decided upon between the air and gas regenerator, the heights of the air and gas chambers being usually made the same.

*Air and Gas Ports or Burners.*—There are almost as many designs of ports as there are designers of furnaces. The end to be obtained by the ports is the proper mixing of the air and gas leading to complete combustion. Present practice in open-hearth furnaces is to have the air enter the furnace above the gas and have the ports inclined so that the air and gas shall mix above the liquid metal. The gas being below prevents excessive oxidation. It does not seem possible that at the velocity of the entering air and gas their difference in density can be advanced as a reason for existing practice. Toldt recommends a high velocity of the air and gas in the ports—about 8 meters (26¼ feet) per second.

The total area of air ports at one end for each 100 pounds of coal burned per hour, 10,200 cubic feet at 1200° C., will require a part section of 0.59 square foot, while 7000 cubic feet of producer gas at

1200° C. will require 0.40 square foot. Campbell recommends that the inclination of the ports provide for a complete mixing of the gas and air at a point about 5 feet above the surface of the bath. This would demand an exceedingly high roof; in usual practice the mixing is much nearer the bath. The distance from fore-plate level to roof at center varies from 4 feet 6 inches on small furnaces to 6 feet on larger ones.

*Hearth.*—The design of the furnace hearth will depend upon the purpose for which the furnace is intended. The proportions of an open-hearth steel furnace hearth alone will be here considered. The following are a few of the important considerations that affect the hearth proportions:

1. The hearth should be sufficiently long that the gas may be completely burned before entering the regenerators, otherwise a large percentage of the heat is lost passing to the stack.

II. The width should not exceed that at which one side can be repaired by placing refractory materials through doors on the opposite side.

Ledebur states that in practice basic furnaces over 15 tons capacity average $7\frac{3}{4}$ square feet of hearth section per ton of product, while acid furnaces average $6\frac{3}{4}$ square feet per ton of product; in both cases these dimensions increase rapidly in smaller furnaces.

The larger surface is made necessary in the basic furnace by the large amount of slag that is formed. If this surface is measured above the sill line, in American basic open-hearth furnaces the section will approximate that stated by Ledebur; the actual bath surface, however, will be between 5 and 6 square feet per ton of metal charged, the usual depth being 15 to 18 inches.

Ledebur limits the inside width of a furnace to $11\frac{1}{2}$ feet, the limiting lengths being $12\frac{1}{2}$ and 40 feet. American practice is about $13\frac{1}{2}$ feet inside width and not exceeding 30 feet in inside length. Ledebur states that in the acid process the capacity of the hearth should be from one-eighth to one-third more than that required for the metal alone according to the amount of ore to be added; while in the basic furnace the hearth capacity should be two-thirds more than that required for the metal alone.

*Furnace Linings.*—The following requirements should be filled by entirely satisfactory furnace linings.

I. They must resist a high temperature, in an open-hearth furnace, 2900° F. (1600° C.).

II. Should not decrepitate when heated.

III. Should resist sudden changes of temperature and not disintegrate when cooled.

IV. Must resist mechanical and chemical action of substances in contact with them.

V. Must have no injurious effect on the product.

VI. Should be easily repaired.

No commercial refractory material meets all these requirements, so that a selection has to be made according to the particular circumstances to be met. The commercial materials are never found entirely pure, and unfortunately the impurities even in small quantities seriously affect their fire-resisting qualities. A fire-clay which in the pure state would be almost infusible, will be fusible if it contains iron oxides, alkalies, lime, magnesia, or large amounts of silica. Lime and magnesia, two separately infusible materials, become fusible by considerable additions of silica or oxide of iron. Much depends upon the treatment of the materials during process of manufacture into bricks or blocks, the form in which most refractory materials for furnaces are used. An analysis therefore will only indicate the possibility of the material; a test under the working conditions to which the bricks will be subjected being the only satisfactory proof of what the material will do.

Ledebur divides refractory furnace-materials into three classes: (I) Those with silica as a foundation; (II) those with alumina as a foundation; (III) basic materials.

I. The silica group is infusible in the usual furnace; the bricks retain their size and form at the highest temperatures; they form a most valuable refractory for the roof and hottest portion of the regenerators. They however cannot be used at high temperatures in contact with alkaline earths, iron, or manganese oxides, or slags rich in these substances. Exposed to rapidly varying temperatures they go to pieces. This group includes sandstone, mica schists, granite, gannister. Among the commercial forms are silica and Dinas bricks. These contain 96 to 97 per cent. silica and 1 to 2 per cent. of lime as a binder, or from 5 to 10 per cent. of fire-clay is used instead of the lime.

II. Pure alumina is practically infusible at the usual furnace temperatures, but in this form does not occur in sufficient quantities for a refractory furnace material. The usual fire-clay is composed of alumina, silica, and impurities. Fire-clay is affected less by basic

materials than silica, and silicious clays attack it less than they do basic materials. Fire-clay is affected less by sudden changes of temperature than silica. It is evident that clay satisfies more of the required conditions of a refractory material than silica.

Pure clay is a hydrated silicate of alumina of the following proportion:

| | Percentage. |
|---|---|
| $Al_2O_3$ | 39.8 |
| $SiO_2$ | 46.3 |
| $H_2O$ | 13.9 |
| | 100.0 |

The water is driven off by burning. At the highest temperatures it shows only slight indication of cindering. All natural clays have impurities mixed with them, sand, oxide of iron ($Fe_2O_3$), alkalies, all of which affect its refractory power. Fire-clay for bricks must be tempered with pulverized quartz, old bricks, burnt clay, or other material producing a similar effect.

Below are a few analyses of fire-clays. No. 1 fire-clay is from Woodbridge, N. J. No. 2 fire-clay is from Woodland, Clearfield Co., Pa. No. 3 fire-clay is from Johnstown, Pa.

| | No. 1. | No. 2. | No. 3. |
|---|---|---|---|
| Silica, $SiO_2$ | 39.80 | 42.15 | 44.95 |
| Alumina, $Al_2O_3$ | 36.34 | 31.43 | 38.84 |
| Water combined, $H_2O$ | 12.90 | 9.40 | 12.50 |
| Titanic acid, $TiO_2$ | with $Al_2O_3$ | 1.60 | 1.55 |
| Sand, $SiO_2$ | 8.10 | 10.25 | 0.30 |
| Potash, soda, lime, oxide of iron, $Fe_2O_3$ | 1.20 | 3.90 | 1.26 |
| Moisture, $H_2O$ | 1.20 | 1.20 | 0.70 |

In general, the clay will be more refractory the greater the ratio of alumina to silica in it.

III. Basic refractory linings. This group includes iron oxide, cinder and slag rich in iron,—these, however, are not suited to high temperatures,—and chrome iron ore, which will withstand exceedingly high temperatures. The more important basic materials, however, are those containing lime, magnesia, or both as a foundation. These substances when pure are infusible, and they are not affected by small amounts of silica, although of course excess of silica would prevent their use as a basic material. Large amounts of iron oxide would give easily fusible combinations with both lime and magnesia.

Dolomite is an important basic material of about the following composition:

| | |
|---|---|
| $SiO_2$ | 2.14 |
| $Al_2O_3$ } $F_2O_3$ } | 0.62 |
| $CaCO_3$ | 55.05 |
| $MgCO_3$ | 42.50 |

Dolomite is prepared by heating to a white heat in a cupola, at which temperature it loses its property of absorbing moisture and carbon dioxide. The burnt dolomite is then pulverized and mixed with a small percentage of tar to act as a binder; this material can either be rammed in place, made into bricks and dried, or pressed into shape by a hydraulic press exerting 5000 to 6000 pounds per square inch on the surface of the brick.

Although magnesite is superior to dolomite as a refractory, its use is limited owing to its cost. Magnesite is less affected by moisture than dolomite and resists the attacks of silica and silicious slags better at high temperatures. The treatment of magnesite is somewhat similar to that of dolomite. It can be burned,—not dead burned,—ground, made into bricks under pressure, and reburned at a white heat. When intended to be rammed into place, it can be treated the same as dolomite and mixed with tar, or the binding material can be milk of dolomite made by adding water to ground dolomite which has been burned but not dead burned.

*Furnace Walls, Flues, etc.*—The manufacturers of fire-bricks furnish a considerable variety of sizes and shapes, and as far as possible these should be used, avoiding cutting and fitting the bricks. The straight clay or silica brick is about 9 inches × 4½ inches × 2½ inches. One manufacturer's catalogue offered thirty-five different shapes of silica bricks and a greater number of clay bricks. From these thirty-five sizes the selection of ten to twelve shapes that could be used to advantage should not be difficult. Fire-bricks are laid in fire-clay grout, 1000 bricks requiring about 700 pounds of fire-clay. The bricks should be laid with joints as thin as possible, using a minimum of the grout.

In a basic furnace the roof and side walls to within 8 or 10 inches of the fore-plate level are silica brick, the roof usually 9 inches thick on account of the difficulty of holding a heavier one; the side walls are quite commonly 13½ inches thick. The lower portions of the side walls are generally magnesite, the extreme portions of the side walls remote from the metal bath and a paving or two on the bottom plates being

clay fire-bricks. Upon this paving the magnesite bricks or blocks are laid, and upon this the hearth proper is formed of rammed dolomite. The bottom at the thinnest part is seldom less than 18 to 24 inches. Flue walls are commonly made from 9 to 18 inches thick. In general, the bottom parts of the furnace are lined with silica brick, where they will not be chemically affected by the materials coming in contact with them; this includes the roof, upper side walls, portions of flues between furnace and regenerators, and the upper portions of the regenerators. The hearth is lined with basic material, and such portions as are likely to have basic slag splashed on them, as side walls above fore-plate level, bottom of parts and back of flues for the last two parts chrome bricks, are especially useful. For all other portions where fire-bricks are required clay bricks are used.

In an acid furnace the hearth proper may be made of sand spread upon a 9-inch paving of fire-bricks. The sand is spread in successive layers, being heated and set after each layer until a depth of 18 to 24 inches is obtained.

## DISCUSSION.

The President.—Mr. Hess has given us a most interesting paper on Regenerative Gas Furnaces, and especially so to those of us who have to do with using the product of these furnaces. We have with us a number of mechanical engineers, and shall be glad to hear from them or from any member of the Club.

James Christie.—It is very desirable to have on record the proportions that Mr. Hess has compiled, especially as these dimensions are derived largely from experience. We have to depend upon experience for the best proportions of flues and passages to permit the desired flow of gases, and the proper allowance to make for extraneous deposits and similar accidental obstructions. One cannot help in observing the action of the regenerative furnace, that although it is the most economical type in use, yet it is at the same time a very wasteful device. Considerable quantities of combustible gas are wasted at the periods of reversal and by reason of leaky valves, etc. These losses usually amount to a good deal in the aggregate

The ordinary gas producer is also wasteful, especially in consideration of the fact that less than one-half of the gas is combustible and the remainder acts as a vehicle to carry the heat of the furnace up the chimney. Notwithstanding this, owing to its simplicity, the gas producer has never been displaced by a more efficient form of generator. The desirable combination is to obtain a producer that is simple, effective, easily cleaned, and that supplies gas with a minimum proportion of non-combustible elements. The furnace end so designed as to be durable, convenient to repair, so constructed as to impart the greatest possible amount of heat to the material to be operated upon, the regenerators designed to absorb the greatest possible amount of the heat that has

escaped from the furnace and that will surrender the stored heat to the incoming air and gas.

Marked improvements have been made, both in gas producers and in regenerative furnaces, during recent years, and considering the arduous nature of the service the results obtained are remarkable.

Mr. Hess.—Regarding the pull in the stack, I certainly had not intended to mislead anybody. I had quite clearly in mind, and thought I had mentioned it, that the stack and the flues leading from the regenerator into the furnace act together in producing the draught. Undoubtedly there is a pressure produced by the air and gas being heated in the regenerators and flues from the regenerators to the furnace. The intention of the stack is then to pull the gases out of the furnace. Whatever tendency the stack has to reduce the pressure in the furnace of course assists the regenerators and the flue from the regenerator to the furnace in forcing more gas into the furnace.

The President.—Is any further discussion desired? We shall be glad to hear from any member. I think I am correct in saying that it is due to those who have given this subject much thought and who have devoted their time to the improvement of the processes and machinery for cheapening the manufacture of steel—it is due, I say, to their efforts, that we are able to use steel in various shapes, instead of wood for building material to-day. I can very well remember the time, and I think I have given the figures from this platform before, when we imported into this country steel rails at $176.00 (currency) per ton. That was not so many years ago, was it Mr. Christie?

Mr. Christie.—Not so very long ago.

The President.—I think it is due to these improved processes that the price of steel has been brought down to the figures of to-day. There was a time, not so many years ago, when we imported nearly all our steel from Sheffield, but that was mostly for the making of tools. Now its manufacture has developed to such an extent in this country that it has largely taken the place of iron We now use steel for almost everything; we use very little iron. Iron is as scarce relatively to-day as steel was forty years ago. I think that is not putting it too strongly; and all these changes in conditions have been brought about by the labors of those who have given their time to the improvement of the processes of manufacture, from the time of Siemens down to the present. This has been an interesting paper, and we are indebted to Mr. Hess for bringing this subject so plainly before us.

# ABSTRACT OF MINUTES OF THE CLUB.

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Regular Meeting, October 3, 1903.—President Edwin F. Smith in the chair. Seventy-two members and visitors present.

Mr. Wm. H. Heulings, Jr., read a paper upon "Development of the Brill System of Trucks for Electric Motor Cars."

Regular Meeting, October 17, 1903.—Vice-President Comfort in the chair. Sixty members and visitors present.

Mr. Henry Hess presented the subject of "Foundry Costs; their Analysis and Reduction."

Regular Meeting, November 7, 1903.—President Edwin F. Smith in the chair. Eighty members and visitors present.

Mr. Walter Loring Webb read a paper entitled "Notes on the Construction of an Electric Road and Power-house at Morgantown, W. Va.,"

Business Meeting, November 21, 1903.—President Edwin F. Smith in the chair. One hundred and six members and visitors present.

The Nominating Committee presented the following nominations for officers:

| | |
|---|---|
| *For President,* | Carl Hering. |
| *For Vice-President,* | Thos. C. McBride. |
| *For Directors,* | Wm. Easby, Jr.<br>George C. Davis.<br>Washington Devereux. |
| *For Secretary,* | J. O. Clarke. |
| *For Treasurer,* | Geo. T. Gwilliam |

The Tellers reported the election of Messrs. Wm. B. Brendlinger, H. T. Campion, Bernard T. Converse, Harry C. Heaton, Herbert F. Moore and G. I. Vincent to active membership.

Mr. R. W. Lesley opened a topical discussion on "The Cement Age," and "The Many New Uses and Increasing Demand for Plastic Materials," which was participated in by Messrs. Christie, Humphrey, and others.

Regular Meeting, December 5, 1903.—President Edwin F. Smith in the chair. Sixty-six members and visitors present.

Mr. H. D. Hess read a paper upon "Proportions of Regenerative Gas Furnaces, with Special Reference to Open-hearth Furnaces."

Business Meeting, December 19, 1903.—President Edwin F. Smith in the chair. Ninety members and visitors present.

The Tellers reported the election of Messrs. Herbert S. Fullerton, S. H. Goodenough, Eugene D. Hays, W. T. Newcomb, A. F. Rader, and Fred. G. Thorn, Jr., to active membership, and Mr. Wm. Harman to junior membership.

After the meeting the members participated in an enjoyable smoker.

# ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

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Regular Meeting, October 17, 1903.—Present: Vice-Presidents Comfort and Foster, Directors McBride, Roegner, Bonner, Leiper, the Secretary and the Treasurer.

The Treasurer's report showed:

| | |
|---|---|
| Balance, August 31st, | $1104.42 |
| September receipts, | 210.00 |
| | $1314.42 |
| September disbursements, | 234.48 |
| Balance, September 30th, | $1079.94 |

Regular Meeting, November 21, 1903.—Present: President Edwin F. Smith, Vice-Presidents Comfort and Foster, Directors McBride, Myers, Reigner, and Leiper, and the Secretary.

The Treasurer's report showed:

| | |
|---|---|
| Balance, September 30th, | $1079.94 |
| October receipts, | 521.80 |
| | $1601.74 |
| October expenditures, | 689.41 |
| Balance, | $912.33 |

The Library Committee reported that the Reference Library had been indexed and that the society publications are now indexed and filed together.

The chairmen of the Membership, Information, and House Committees were made a special committee of entertainment for the club smoker to be held on the second meeting of December, for the purpose of properly introducing the many new members that have been elected this year.

The prices for copies of "Proceedings" were revised as follows:

50 cents per copy to the general public.
25 cents per copy to members and newsdealers.

Authors may secure additional copies of "Proceedings" in which their papers appear at cost, if ordered before going to press.

Regular Meeting, December 19, 1903.—Present: President Edwin F. Smith, Vice-President Comfort, Directors Riegner, Myers, Bonner, and Leiper, the Secretary and the Treasurer.

The Treasurer's report showed:

| | |
|---|---|
| Balance, October 31st, | $912.33 |
| November receipts, | 279.45 |
| | $1191.78 |
| November disbursements, | 442.99 |
| Balance, | $748.79 |

The following named junior members were transferred to the active list, Messrs. Wm. C. Kerr, Carl Rossmassler, and R. Robert Yarnall.

Mr. John T. Loomis was appointed to fill the unexpired term of Mr. D. A. Hegarty, Director.

The salary of Mr. Fred'k W. Myers, Clerk, was increased five dollars per month, dating from January 1, 1904.

Resignations from active membership were accepted from the following: Messrs. G. C. Schoff, Wm. E. Mott, J. Ogden Hoffman, E. C. Felton, R. Khuen, Jr., T. Kolischer, Chas. J. Dougherty, and J. M. Cox.

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# ADDITIONS TO GENERAL LIBRARY.

From Emil L. Nuebling, Reading, Pa.

Thirty-eighth Annual Report, Board of Water Commissioners, Reading, Pa.

From Ray D. Lillibridge, New York.

"The Influence of Electricity on the Development of Water Powers." Pamphlet by F. A. C. Perrine.

From the Commissioner of Education, Washington, D. C.

Annual Report, Vol. I, 1902.

From Boston Transit Commission, Boston, Mass

Ninth Annual Report, June 30, 1903.

# THE ENGINEERS' CLUB OF PHILADELPHIA,

**House, No. 1122 Girard Street,**

PHILADELPHIA, PA.

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## ANNUAL REPORT OF THE BOARD OF DIRECTORS

**For the Fiscal Year 1903**

JANUARY 2, 1904.

TO THE ENGINEERS' CLUB OF PHILADELPHIA:

In compliance with the requirements of the By-Laws, the Board of Directors offers the following report for the year ending December 31, 1903.

One special and 17 regular meetings of the Club were held, at which the maximum attendance was 135, and the average 84 The increased average attendance for 1903 over 1902 is about 19 members. Nine stated and 3 special meetings of the Board of Directors were held.

Forty-eight active, 5 associate, and 7 junior members were elected, and 1 active member reinstated; 13 active members resigned; 1 associate and 4 active members were dropped from the rolls; 3 junior members were transferred to the active list.

The record of deaths is:

Geo. W. Hancock, Active Member, died March 22, 1903.

Henry A. Vezin, Active Member, died December 27, 1902.

The membership of the Club on December 31, 1903, as compared with the previous year was as follows:

| | 1902. | | | 1903. | | |
|---|---|---|---|---|---|---|
| *Class.* | *Resident.* | *Non-Resident.* | *Total.* | *Resident.* | *Non-Resident.* | *Total.* |
| Honorary | 1 | 6 | 7 | 2 | 5 | 7 |
| Active | 299 | 120 | 419 | 336 | 116 | 452 |
| Associate | 14 | | 14 | 18 | | 18 |
| Junior | 12 | 4 | 16 | 16 | 4 | 20 |
| | 326 | 130 | 456 | 372 | 125 | 497 |

The following papers have been presented:

JANUARY 3D ..... Charles Piez.
The Handling and Storing of Iron Ore.

JANUARY 17TH ..... Henry J. Hartley.
Address of Retiring President.

JANUARY 31ST ..... Henry Wiederhold.
Asphalt and Asphalt Mastics.

FEBRUARY 7TH ..... Joseph L. Ferrell.
Apparatus for and Methods of Treating Wood to Protect it from Fire and Preserve it from Decay.

FEBRUARY 21ST ..... John W. Hill.
Improvement, Extension, and Filtration of Water Supply of Philadelphia.

MARCH 7TH ..... H. B. Schermerhorn.
The State of the Art in Patent Cases.

MARCH 21ST ..... Howard W. DuBois.
Reconnaissance Methods of Surveying in a Mountainous District.

APRIL 4TH ..... L. Y. Schermerhorn.
Obstruction of the Navigation of Southern Rivers by the Growth of the Water Hyacinth.

APRIL 4TH ..... E. K. Landis.
Richards' Prismatic Stadia Used as a Rangefinder.

MAY 2D ..... Rear Admiral Geo. W. Melville.
The Military Importance of Naval Engineering Experiments.

MAY 16TH ..... A. L. Baldwin.
Recent Rapid Base Line Measures, Precise Leveling, and Triangulation.

JUNE 6TH ..... Henry G. Morris.
A Consideration of the Gaseous Fuel Problem.

SEPTEMBER 19TH ..... Henry Leffmann.
The Borderland of Biology and Engineering: Exemplifications of Engineering Principles in Living Structures.

OCTOBER 3D ..... Wm. H. Heulings, Jr.
Development of the Brill System of Trucks for Electric Motor Cars.

OCTOBER 17TH ..... Henry Hess.
Foundry Costs; Their Analysis and Reduction.

NOVEMBER 7TH ..... Walter Loring Webb.
Notes on the Construction of an Electric Road and Power House at Morgantown, W. Va. Topical Discussion.

NOVEMBER 21ST ..... R. W. Lesley.
The Cement Age, the Many New Uses and Increasing Demand for Plastic Materials. Topical Discussion.

DECEMBER 5TH ..... H. D. Hess.
Proportions of Regenerative Gas Furnaces, with Special Reference to Open Hearth Furnaces.

DECEMBER 19TH ..... Informal Smoker.

Members and their friends inspected the asphalt works of the Vulcanite Paving Company, at Long Island City, and the New York Subway, on February 7th, and visited the works of the J. G. Brill Company on October 3d, as arranged by the Information Committee.

Special attention is called to the Reference Library, which has been thoroughly indexed and cross-indexed.

A new table has been placed in the auditorium for the use of the President and Secretary and new cases placed in the Reference Library room.

The furniture and fixtures of the house are in excellent condition.

NET EXPENDITURES FOR 1903.

| | |
|---|---|
| House | $2524 55 |
| Proceedings and Directory | 931 81 |
| Library | 105 91 |
| Information | 43 70 |
| Office | 643 78 |
| Salaries | 1735 00 |
| | $5984 75 |

ASSETS, DECEMBER 31, 1903.

| | | |
|---|---|---|
| Furniture and fixtures, as per appraisement February 17, 1900, with subsequent additions | $1947 26 | |
| Library, as per appraisement February 10, 1900, with subsequent additions | 2360 56 | |
| Total furniture and library | | $4307 82 |
| U. S. Bond, issue of 1898 (par $500), market value | | 532 50 |
| On deposit, bearing interest at three per cent | | 561 49 |
| On deposit, bearing interest at two per cent. (including $705 dues for 1904) | | 751 11 |
| | | $6152 92 |

THE CLUB HAS NO LIABILITIES.

The Board congratulates the Club on the unusual increase in membership during the past year, which was doubtless due in large measure to our very successful Twenty-fifth Anniversary Banquet, held in December, 1902, and to the interesting and instructive visits to manufacturing establishments and engineering works made during the year.

Respectfully submitted,

EDWIN F. SMITH, *President.*

J. O. CLARKE, *Secretary.*

## Report of the Treasurer for the Fiscal Year 1903.

*Receipts.*

| | | |
|---|---|---|
| Initiation fees (60) | $300 00 | |
| 1901 dues | 15 00 | |
| 1902 dues | 285 00 | |
| 1903 dues | 4592 50 | |
| 1904 dues | 705 00 | |
| | | $5897 50 |
| Proceedings: | | |
| Advertisements | 304 50 | |
| Sales | 93 90 | |
| Reprints | 145 80 | |
| | | 544 20 |
| 1903 Directory advertisements | | 600 00 |
| Interest on deposits | | 42 99 |
| Interest on investment | | 15 00 |
| Telephone | | 5 21 |
| Billiards | | 34 05 |
| Lantern slides | | 3 15 |
| Binding books | | 2 00 |
| Total receipts | | $7144 10 |
| Cash balance, Dec. 31, 1902 | | 1341 86 |
| | | $8485 96 |

*Expenditures.*

| | | |
|---|---|---|
| Salaries: | | |
| Secretary | $240 00 | |
| Treasurer | 60 00 | |
| Clerk | 895 00 | |
| Janitor | 540 00 | |
| | | $1735 00 |
| House: | | |
| Rent | $1100 00 | |
| Coal | 133 60 | |
| Gas and electric light | 120 58 | |
| Ice | 31 97 | |
| Supplies and repairs | 344 82 | |
| Telephone | 143 89 | |
| Insurance | 12 00 | |
| | | 1886 86 |
| Office expenses | | 672 23 |
| Proceedings | | 1611 46 |
| Information Committee | | 43 70 |
| Library | | 108 71 |
| Luncheons | | 655 40 |
| 1903 Directory | | 460 00 |
| Total disbursements | | 7173 36 |
| **CASH BALANCE, DEC. 31, 1903** | | **1312 60** |
| | | $8485 96 |

Respectfully submitted,
Geo. T. Gwilliam, *Treasurer.*

Philadelphia, Jan. 4, 1904.

We have examined the books and accounts of the Treasurer, compared them with the original vouchers, checks, and bank books, and found them to correspond with the Treasurer's statement submitted above.

W. P. Dallet,
H. W. Spangler,
Rich'd L. Humphrey, } *Auditors*

January 13, 1904.

Edwin F. Smith.

Twenty-sixth President of the Club, January 17, 1903—January 16, 1904.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXI. APRIL, 1904. No. 2

# SOME EARLY ENGINEERING WORKS IN PENNSYLVANIA.

## ADDRESS BY THE RETIRING PRESIDENT,

EDWIN F. SMITH.

*Read January 16, 1904.*

JUST a quarter of a century ago, on the evening of January 8, 1879, the first President of the Engineers' Club of Philadelphia, in closing the work of the year and resigning the office to his successor, delivered what has come to be known as the Annual Address, in which he spoke of the event as "the last chapter in the first volume of our history." To-night we close the last chapter in the *twenty-fifth volume*, completing a quarter century of Club life, which I am glad to say has been continuously active, has established the Club on a firm foundation, and has prepared the way for even greater achievements in the future.

In membership we have, with the close of the year, reached the five hundred mark, while the average attendance at our semi-monthly meetings has grown to eighty-four, a greater number than ever before. When we remember the purpose for which the Club was organized, namely, "the professional improvement of its members, the encouragement of social intercourse among men of practical science, and the advancement of engineering in its several branches," we may congratulate ourselves that so many, after the labors of the

week in the office and in the field, are willing to meet together for mutual help in the theory and the practice of our profession. In this we have been aided by having comfortable quarters, and by having about us the weekly and monthly engineering publications of the day, covering a wide field, by which the Club has placed within the reach of its members the means of keeping informed on current topics of engineering. The library has grown to be a good beginning, and, since "of making many books there is no end," we may hope that some day the Club will find itself in possession of a complete reference library.

The advance of the engineering profession within less than a century is in no way more manifest than in the multiplication of facilities for its development into an exact science. Going back to the year 1820, the President of one of the works of internal navigation of the State of Pennsylvania, in a report to the stockholders, says: "In the progress of this arduous and novel undertaking the managers have had great obstacles to encounter, the first of which is the procuring of skilful persons to execute the work."

This difficulty was experienced by the promoters of public works in Pennsylvania until nearly the middle of the nineteenth century. There was a scarcity of educated civil engineers, for there was no school in the United States devoted to their training until the year 1824, when the Rensselaer Polytechnic Institute was founded, and even in that the course of instruction was, at the first, by no means comprehensive.

Of text-books there were few indeed; the civil engineer engaged in field work having only the "Railroad Manual, or a brief exposition of principles and deductions applicable in tracing the route of a railroad," by S. H. Long, Bt. Lt. Col. of Engineers, in the service of the Baltimore and Ohio Railroad. Part 1, 1829; Part 2, 1836.

This little work was the forerunner of the "Pocket Book" of which we now have so many. In the preface the author says: "The design of the following little work is to place in the pocket of the engineer a brief and perspicuous compend of easy rules that may serve as a directory to guide him in tracing the route of a railroad."

Among the few other text-books may be noticed "A Treatise on Canals and Reservoirs, and the Best Mode of Designing and Executing Them," etc., by John Sutcliffe, Civil Engineer, 1816, and "An Elementary Course of Civil Engineering," translated from the French of M. I. Sganzin, with notes and applications adapted to the United States, published in 1827, in which, quoting from the preface, it is

said: "The object of the translator in presenting this work to the public is to do something to supply what seems to him a great deficiency in the books on practical science in this country. He is acquainted with no work in English which contains, within a small compass, and in a form intelligible to common readers, those elementary principles of Engineering which relate to building in stone, brick or wood, and making roads, bridges, canals and railways."

The work of Sganzin had long had a high reputation in France, and was used as a text-book in the Department of Civil Engineering at the Royal Polytechnic School in Paris. In 1823 it was adopted at the United States Military Academy at West Point. To it the translator added a chapter on railways, compiled from the best English authorities, from which we quote some curious observations on the construction of railroads in those early days: "There are two kinds of rails which succeed in practice; these are the cast and wrought iron ones. Wrought iron does not last so long as cast iron when exposed to the air and weather. A cast iron rail is more liable to fracture than a wrought iron one, even when made of the best of iron, and the force that would break a cast iron bar would only bend a wrought iron one, which would not interrupt the traffic on the road"; and the following "Rule for the Best Length of Rails of Railroads": "The price of a ton of iron delivered on the railroad must be known, and also the price of the chair, stones and setting one support. Then divide the price of a ton of iron by the price of one support, both being in dollars; square the quotient and multiply it into the breadth of the rail in inches, and this product by one-twentieth part of the weight of the loaded wagon in pounds, and extract the cube root of the product; divide 700 by the cube root found, and the result will be the distance in feet." To which the author adds this note: "This is for cast iron; every precaution should be adopted for keeping the rails dry."

In the field of mechanics the early text-book was "The Elements of Mechanics," by James Renwick, LL.D., of Columbia College, New York. Published in 1832.

Nevertheless, with all his disadvantages in field and in office, his hardships in the primeval forests, and the lack of facilities for the prosecution of his work, the early civil engineer was full of resources; and, as the inventions of the last century were brought forth, and money became more plenty for installing and using them, he was ready to welcome and adopt new ideas and improved methods.

As for the mechanical engineer, his time had not yet come. His

predecessor, the expert mechanic, was wrestling with the best form of steam boiler, with a tank built of white oak plank and an interior firebox of cast iron. The locomotive engine existed only in the mind of man and in his dreams.

And so, after Commissioner's dams in the rivers of Pennsylvania, with arks and rafts as the only means of transportation other than the turnpikes and the Conestoga wagon, came canals of small size, and railroads with inclined planes, built by early engineers, with limited facilities and experience; and with these came the period when our engineering schools for technical training were founded and students were taught the theory and practice of engineering as applied to modern structures.

Nothing more clearly illustrates the need, at that time, of technical education in engineering than the comments which are found in an early report, 1838, of the Little Schuylkill and Susquehanna Railroad, a line which had been admirably located by Edward Miller, an accomplished civil engineer and a citizen of Philadelphia.

The high bridges upon this line were a source of anxiety to the builders, there being no precedents for such structures for railway traffic. They were, therefore, purely experimental, and in commenting upon the first one, 579 feet in length, the chief engineer, Solomon W. Roberts, says in his report: "The superstructure is of very strong lattice work, having three sets of lattice spans, well braced together. The length of the single span is 200 feet, which is that of the longest span upon the line." Then follows this remark: "This bridge was completed before the others in order to judge whether additional strength would be needed, and if so, to learn the best mode of applying it." Also: "The lattice bridges are free from lateral thrust, and being continuous throughout, may be supported at any point indiscriminately. Such being the case, and the rivulets offering no obstruction, I propose that when the superstructure of each bridge is completed, the keys of the falseworks shall be loosened, and the falseworks allowed to remain standing within a few inches of the lower chords of the bridge, so as to obviate the possibility of accident, and, if found necessary, timber framed piers may be built half-way between the stone ones, so as to shorten the spans one-half, and to render the bridge more than strong enough to sustain any possible load. This will not be a very expensive expedient, and it must be conclusive."

It was on this line of railroad, now the Catawissa Branch of the Philadelphia & Reading Railway, and for the support of these same

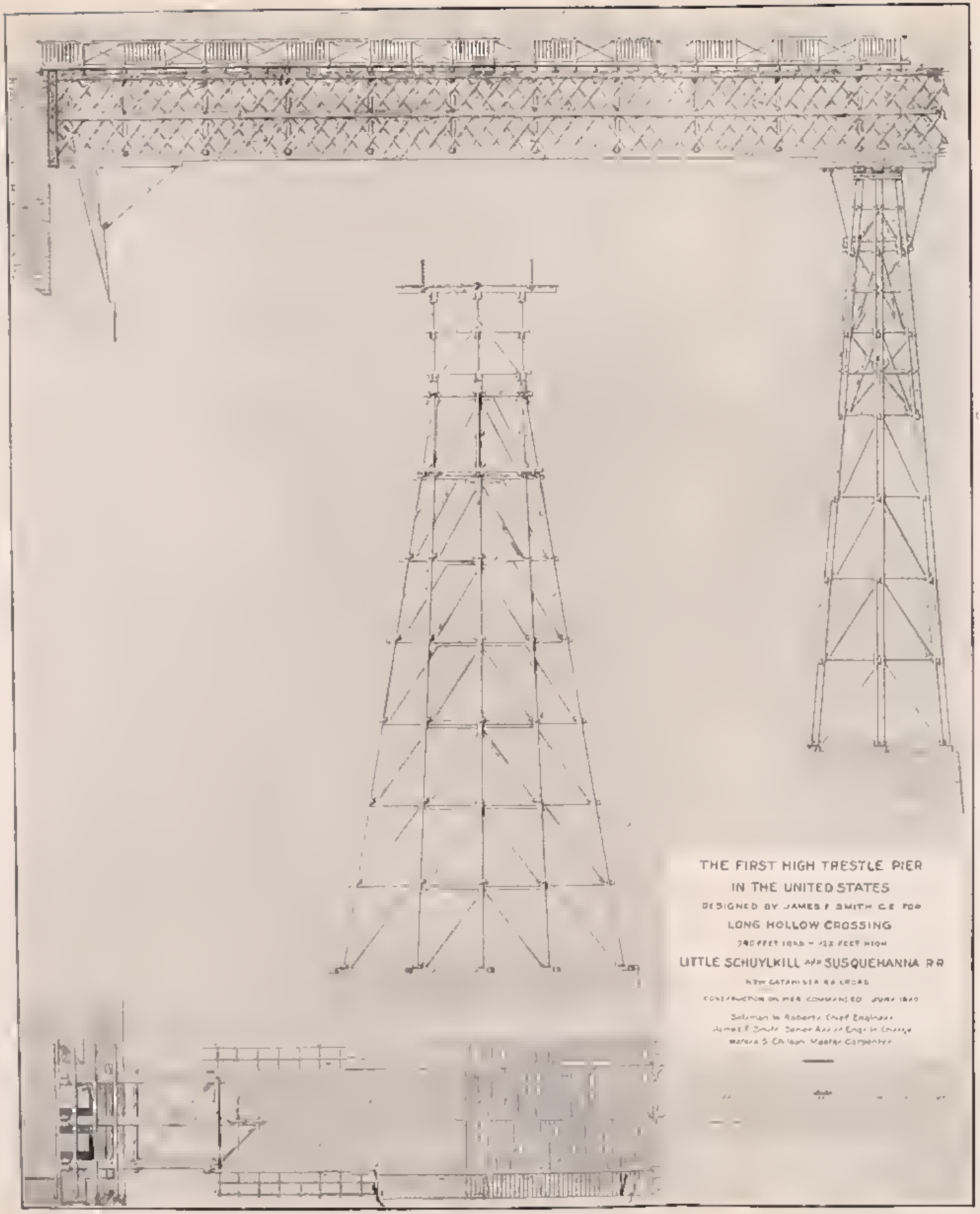
THE FIRST HIGH TRESTLE PIER
IN THE UNITED STATES
DESIGNED BY JAMES F SMITH C.E. FOR
LONG HOLLOW CROSSING
LITTLE SCHUYLKILL AND SUSQUEHANNA R.R.

Fig. 1.

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lattice truss bridges, that the first high trestles or timber framed piers in the country were built in the year 1840, work having commenced on the Long Hollow Trestle in June of that year. They varied in height from 53 to 129 feet, and in length of superstructure supported, from 600 to 1000 feet. They marked the beginning of high structural works in timber, and were essentially the same in principle as the constructions in steel now employed for the same purposes on railroads, as well as for the skeletons of the high buildings of the present day. They were designed by James F. Smith, Principal Assistant Engineer, who had obtained his early training on the Allegheny Portage Railroad; the woodwork of the working model being made by him, and the bolt-work by the late Ellerslie Wallace, M.D., Dean of Jefferson Medical College in this city, then an assistant engineer on the Catawissa Railroad. This model, which is now deposited with the Franklin Institute in this ciiy, was placed upon a solid foundation and subjected to a weight of 6460 pounds, without causing the least deflection in the posts, when the test was discontinued. In this practical way, without any calculations whatever, the sufficiency of the trestle piers for sustaining a railway bridge was demonstrated. The same plan of trestle was shortly after adopted for the Portage Viaduct over the Genesee River, on the New York and Erie Railroad, by Silas Seymour, Civil Engineer. Thus, from what was designed to fulfil merely a temporary purpose, there was derived the principle embodied in the structural works of the present day.

Only five years after, there was constructed what we have reason to believe was the first iron railway bridge in the United States. It was designed by Richard B. Osborne, Civil Engineer, then Chief Engineer of the Philadelphia and Reading Railroad, and erected in February, 1845, for a double track crossing over a small stream south of Flat Rock Tunnel, near Manayunk. It was in service until the year 1901, but for many years had been carried on timber trestles, on account of the heavy traffic passing over it, for which it had not been designed. It is doubtful whether any other bridge in the country, wooden or iron, carried during its period of usefulness so great an aggregate of tonnage as this, the first iron railway bridge.

With this bridge, as in the case of the timber structures on the Catawissa Railroad, there was the same distrust of new things in engineering, brought about by the entire dependence upon experiment in designing. It is recorded that "it looked very light in comparison with the timber structures," and the suggestion was made

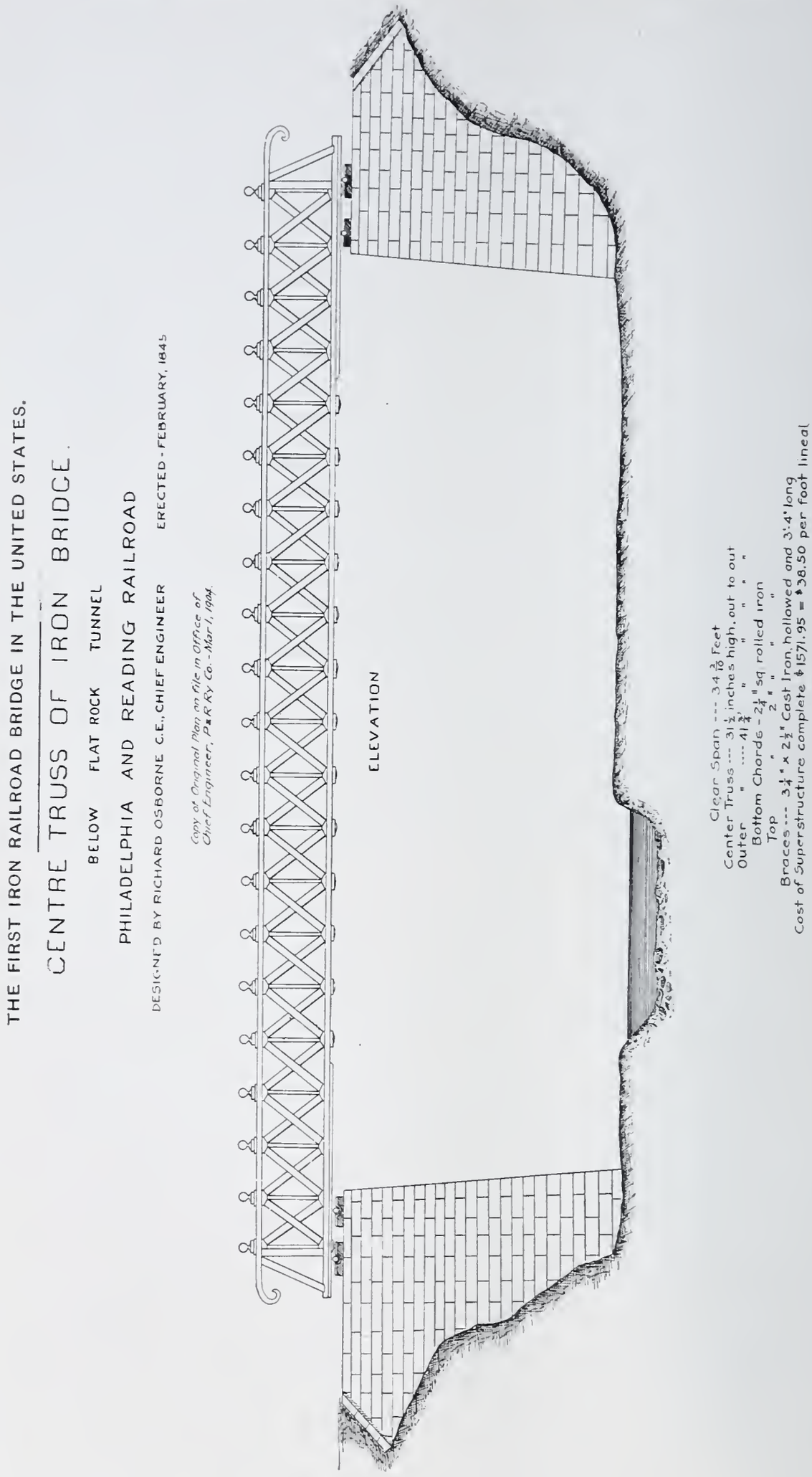

THE FIRST IRON RAILROAD BRIDGE IN THE UNITED STATES.
CENTRE TRUSS OF IRON BRIDGE
BELOW FLAT ROCK TUNNEL
PHILADELPHIA AND READING RAILROAD
DESIGNED BY RICHARD OSBORNE C.E., CHIEF ENGINEER
ERECTED - FEBRUARY, 1845
Copy of Original Plan on file in Office of Chief Engineer, P&R Ry Co. - Mar 1, 1904.
ELEVATION
Clear Span --- 34 2/10 Feet
Center Truss --- 31 1/2 inches high, out to out
Outer " ---- 41 3/4' " " " "
Bottom Chords - 2 1/4" sq rolled iron
Top " " 2" " " "
Braces --- 3 1/4" x 2 1/2" Cast Iron, hollowed and 3'4" long
Cost of Superstructure complete $1571.95 = $38.50 per foot lineal

FIG. 2.

by the President of the Railroad Company that "the falseworks be left stand within half an inch of the bottom chords to give it a longer test." This was done and the falseworks remained for a long time.

*The first tunnel* in the United States was the work of George Duncan, a Scotch civil engineer, who entered the service of the Schuylkill Navigation Company about the year 1820, and designed and built many important works. It was commenced in the year 1821 and completed in September, 1825. It was 450 feet long, through red shale rock, and was without lining. With its completion the navigation works were opened for the transportation of coal from Mount Carbon to Philadelphia. The first six tunnels used for transportation purposes in Pennsylvania and in the United States, in the order of their construction, were:

1. The Schuylkill Canal Tunnel, near Auburn, 450 feet long; commenced 1818, completed September, 1821; George Duncan, Engineer.
2. The Union Canal Tunnel, Lebanon, 729 feet long; 1824–'26; Canvass White, Chief Engineer.
3. The Pennsylvania Canal Tunnel at Conemaugh, 817 feet long; 1828–'30; Alonzo Livermore, Engineer.
4. The Pennsylvania Canal Tunnel, Grants Hill, Pittsburg, 819 feet long; 1828–'30; Nathan S. Roberts, Engineer.
5. The Allegheny Portage Tunnel, 901 feet long; 1831–'33; Sylvester Welsh, Chief Engineer; Solomon W. Roberts, Principal Assistant Engineer-in-Charge.
6. The Black Rock Tunnel, Philadelphia & Reading Railroad, 1932 feet long; 1835–'37; Moncure Robinson, Chief Engineer; W. H. Wilson, Resident Engineer-in-Charge.

George Duncan also designed and constructed what I am inclined to believe was the first impounding reservoir of large dimensions in the State of Pennsylvania, and indeed in the United States. It was built in the years 1832–33 in the Tumbling Run Valley, near Mount Carbon, as part of the water-supply of the Schuylkill Navigation, and was an earthen or mound dam 418 feet in length and 48 feet in height. A second dam of the same type, 540 feet in length and 60 feet in height, was built in the same valley by Edward F. Gay, Civil Engineer, in the years 1835–37. These reservoir dams are still in use and serving the purpose for which they were designed. It may be of interest to know that they are puddled embankments, without core walls, and that in those early days the use of grooved rollers on such works in Pennsylvania was unknown.

Among George Duncan's other works were dams for slackwater

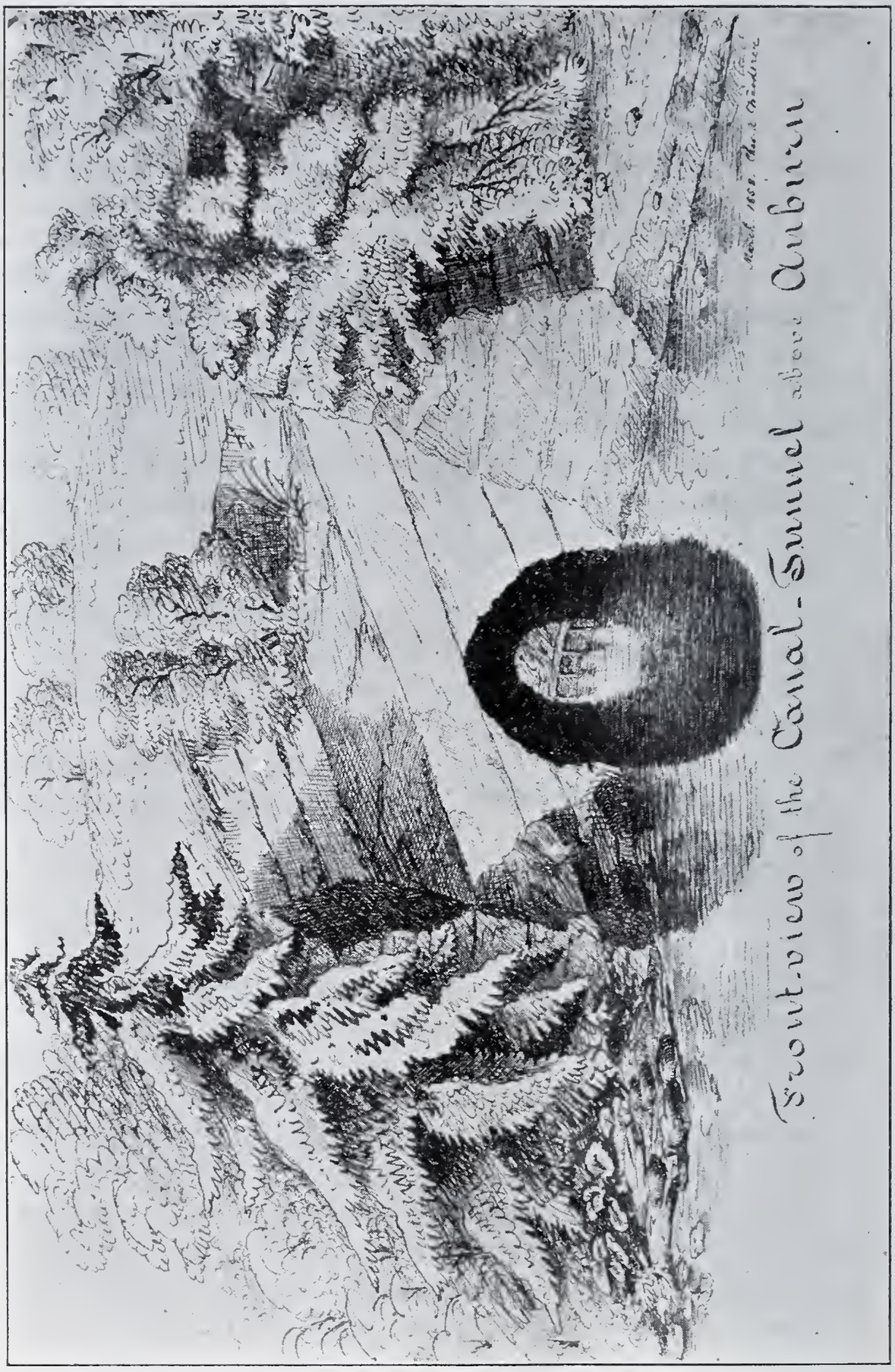
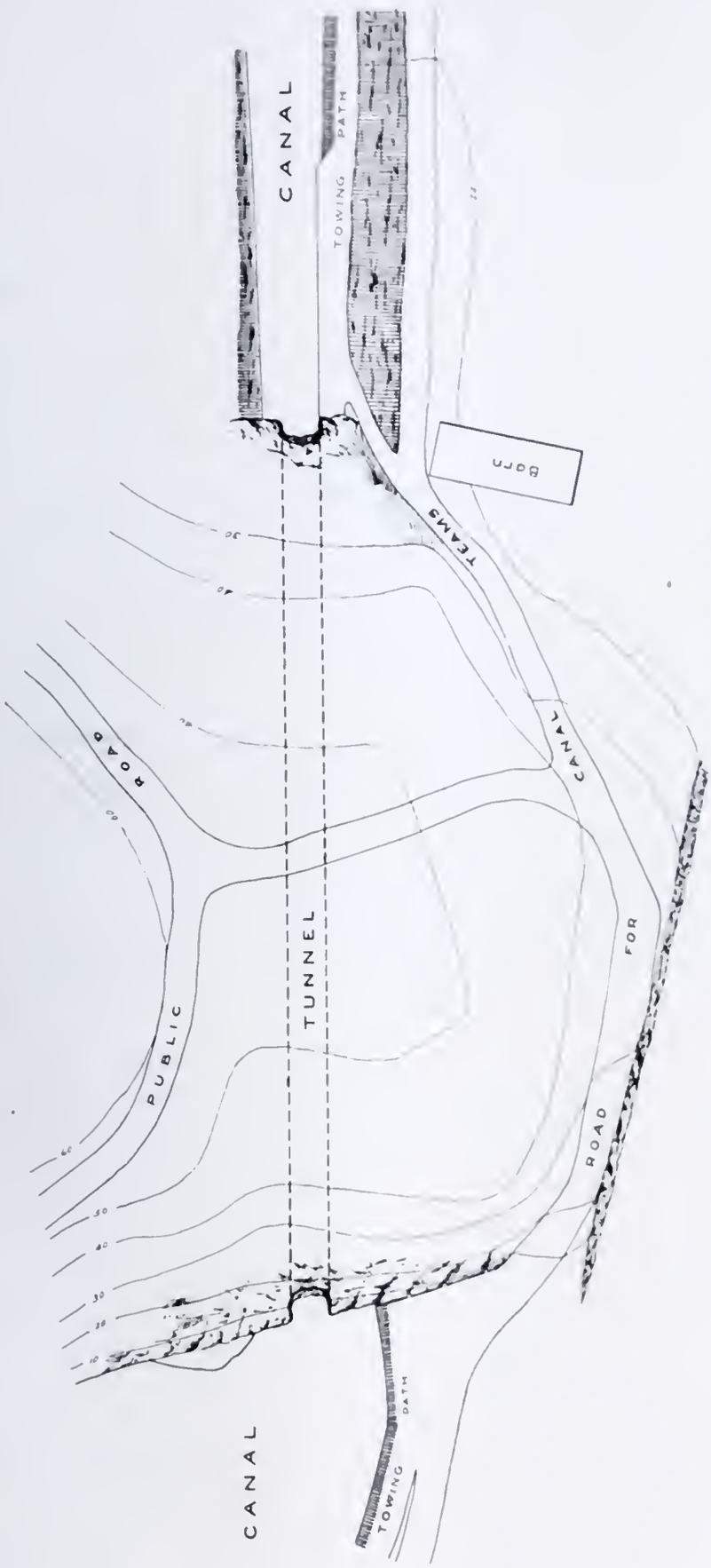



Fig. 3.




THE FIRST TUNNEL IN THE UNITED STATES

IN USE UNTIL 1862 ON THE SCHUYLKILL CANAL NEAR AUBURN PENNA.

LENGTH - 450 FEET GEORGE DUNCAN, ENGINEER BUILT - 1818-21

FIG. 4.

navigation, and canals and hydraulic works in connection with them, all of which show the master-mind in engineering design and construction. Two timber dams in particular have been in use since the year 1833 for slackwater navigation, without accident and without rebuilding. He was a man of great energy, strength of character and originality. Many of the problems which confronted him were without precedent in this country, and yet he overcame all obstacles and built works which not only have survived until to-day, but are still useful.

It was during the construction of a line of six miles of slackwater navigation on the upper Schuylkill that George Duncan built and operated for some years a mill for the manufacture of hydraulic cement. It was built about the year 1831 and was operated successfully until 1850, when it was destroyed by the great flood of that year. The natural cement produced was of a high grade, as is now plainly to be seen in taking down masonry laid with it. This cement mill was one of the first in the United States. One at Rondout, New York, was built at about the same time.

The Enigneer-in-Chief of the first works of the Schuylkill Navigation was Thomas Oakes, another civil engineer, of whom little is known, who came from England early in the nineteenth century, and of whom the only mention is that "he must have been an engineer of ability." This, indeed, is evidenced by many of his works, which are still standing and show his skill in designing and building. He died in 1825, shortly before the completion of the line extending from Philadelphia to Mount Carbon. His death was followed almost immediately by the death of Mr. King, another engineer, presumably his assistant. It is recorded of these men that "their death interposed obstacles in the way of the prosecution of the work not easily surmounted, nor without much delay."

Mr. King, whose Christian name we do not know, made the first plans for the improvement of the navigation of the Delaware River, as proposed by the Lehigh Coal & Navigation Company, about the year 1825, and antedating the works of the Delaware Division Canal.

Of the early railways, the Mauch Chunk Railway, nine miles long, connecting the anthracite mines of the Lehigh Coal & Navigation Company with the Lehigh Canal, was the second in the State; the first being a tramway, one mile long, in Delaware County, built in 1806. The Mauch Chunk Railway was commenced January 8, 1827, under the superintendence of Josiah White, and completed so as to pass "wagons" in three months and twenty-six days.

The rails were laid upon sills of sawed white oak timber, which were laid upon a roadbed properly prepared and embedded in broken stone. These sills were 6 feet long, extending across the road, and had two sawed notches, which received the wooden rails of sawed white oak timber, 5 inches by 7 inches, and $3\frac{1}{2}$ feet apart. Upon these rails was laid strap iron, $\frac{3}{8}$ inches thick by $1\frac{3}{4}$ inches wide and 14 feet long, with an allowance of $\frac{1}{16}$ of an inch between the rails for temperature.

The Lehigh Canal was commenced in the summer of 1825 under direction of Josiah White, who was an engineer by instinct and self-training, if not by profession, and who constructed the works, including the basin in the neighborhood of Mauch Chunk. In June, 1827, the canal from the end of the first mile was undertaken under the superintendence of Canvass White, Civil Engineer, who laid out and constructed the line from Mauch Chunk to Easton, a distance of $46\frac{3}{4}$ miles.

The chain of State works, stretching from Philadelphia to Pittsburg, and connecting the Ohio River with the seaboard, known as the "Pennsylvania Internal Improvements," was first agitated in the year 1823, and bore the same relation to the commerce of Pennsylvania that the Erie Canal, at the same time, bore to that of the State of New York.

The first appropriation for these works was made by the State of Pennsylvania on February 25, 1826—$300,000.00—for canal construction. The first contracts were dated June, 1826, and the first ground was broken on July 4th of the same year. It was a great undertaking, engaging the best thought and efforts of the leading civil engineers of the State and country at a period, indeed, which antedated the definition of our profession as "the art of directing the great sources of power in nature for the use and convenience of man." The discomforts of traveling by stage, and the labor and hardship involved in wagoning goods from the seaboard to the West, had made these works of internal improvement, which were the predecessors of the Pennsylvania Railroad, not only necessary to the convenience of man, but necessary to his comfort as well. A more modern definition of civil engineering, embracing all its branches, as distinguished from military engineering, would surely add the word comfort; for how many of the great works of the age are constructed solely for our convenience and comfort!

We, who are accustomed to the use of modern appliances, can appreciate that the problems involved in the designing and con-

struction of these early canals and railroads were, to the engineers of that day, when everything was done with the hands, or, as it were, by "brute force," an even greater undertaking than the largest works of the present day.

The State works from Philadelphia to Pittsburg were composed of canals and railroads in five divisions.

The Columbia and Philadelphia Railroad commenced in the city of Philadelphia, at the intersection of Broad and Vine Streets, and followed the abandoned bed of the Union Canal, now Pennsylvania Avenue, to a point on the Schuylkill near Peter's Island, crossing the river by a bridge of seven spans to the west bank to the foot of the first inclined plane. This plane was 2714 feet long, and its elevation 185 feet, a portion of it now being occupied by the roadbed of the Fairmount Park Transportation Company. From the head of this plane the route extended by an undulating line, with numerous and very sharp curves, through what was at that time considered the most highly cultivated, populous, and wealthy section of Pennsylvania, to the Susquehanna River, a distance of 77 miles.

The maximum grade, exclusive of the planes, did not exceed 30 feet to the mile, and the sharpest curves were of a radius of 630 feet; descent was made to the Susquehanna River by a second inclined plane, 1914 feet long, with an elevation of 90 feet.

These planes were operated by stationary steam-engines of 45 horse-power, and it was said at the time, that although the amount of tonnage going eastward would greatly exceed that going westward, the engine at the Schuylkill, though acting on a longer plane and one of greater elevation than at the Susquehanna, would still be able to forward the tonnage to any extent required. The largest bridge on the line was across the Conestoga, near the city of Lancaster. It was built of timber on the lattice truss plan. It was 1400 feet long and had eleven spans. The piers were of masonry, the highest being 60 feet. The engineer of the Columbia and Philadelphia Railroad was Major John Wilson.

From the terminus of the Columbia and Philadelphia Railroad, the Susquehanna Division was a canal, commencing in a basin, 237 feet above tide, following the Susquehanna River, passing through Middletown and Harrisburg, crossing the river at Duncan's Island and terminating at the mouth of the Juniata River. At Middletown, in a basin constructed for the purpose, it was joined by the Union Canal, one of the earliest works projected in Pennsylvania, which was opened for traffic in the year 1827.

One of the greatest undertakings in connection with this division seems to have been the crossing of the Susquehanna at Duncan's Island, now known as the Clarks Ferry Dam. The first dam was erected on plans by William Strickland, who had been appointed in December, 1825, as Consulting Engineer, to prepare maps and make estimates of the canal lines. It was on this section, from Middletown to the mouth of the Juniata River (William Strickland's location), that on the 4th of July, 1827, the first ground was broken near Harrisburg, in the construction of the great system of Pennsylvania's line of internal improvements.

The first dam on the site of the present Clarks Ferry Dam was nothing more than a winrow of loose stones, or what might be called a rock-fill dam. It was destroyed by the flood of 1830 and was replaced by one of larger proportions from plans of Sylvester Welsh and Edward F. Gay, two distinguished civil engineers. It was 1998 feet in length and 8½ feet high, and was built of crib-work covered with heavy timber, and was completed in eighty-five days from the date of contract.

The Juniata Division commenced at Duncan's Island and extended to Hollidaysburg, and followed the valley of the river from which it derived its name. This division was made up of canal and slack-water navigation, much of it of difficult construction. There were 25 aqueducts on the line of the division, the longest 600 feet; and it is worthy of note that one of the aqueducts, crossing Buffalo Creek, was of cast iron. The remainder of them were carried on masonry abutments and piers, with wooden superstructure.

DeWitt Clinton, Jr., was the engineer who located and superintended that portion of the canal, between Duncan's Island and Huntingdon, from the beginning of the work almost until its completion, and Edward F. Gay was the engineer of that part of the line between Huntingdon and Hollidaysburg, where connection was made with the Allegheny Portage Railroad.

Quoting from a recent writer: "The Allegheny Portage Railroad was considered, in its day, a marvel of engineering skill, which David Stevenson, a distinguished engineer, in 1838, described as 'a mountain railway, which, in boldness of design and difficulty of execution, can compare to no modern work I have ever seen, excepting, perhaps, the passes of the Simplon and Mount Cenis in Sadinia; but even those remarkable passes, viewed as engineering work, did not strike me as being more wonderful than the Allegheny Mountain Railway in the United States.'" Much has been written descriptive of this work

It took its name from the Indian trail passing over the mountains at Blair's Gap, which was the only route suitable for the transportation of freight over the mountains. So it took the name "Portage."

It was located and the system of works designed in the year 1829 by Moncure Robinson, a distinguished civil engineer, who a few years later located and built the Reading Railroad, and whose report on the Allegheny Portage Railroad, dated November 28th of that year, was subsequently approved by a Board of Engineers, appointed by the Canal Commissioners of the State of Pennsylvania. On the 31st of March, 1831, the road was placed in charge of Sylvester Welsh as Principal Engineer, with Moncure Robinson as Consulting Engineer to make the final location, and on the 25th of May, 1831, the work of construction was begun.

The road consisted of levels and inclined planes, it being considered in those days impracticable to surmount as much as one per cent. grade with a locomotive. Its length was 36.69 miles, in which was overcome an ascent and descent of 2570 feet, of which 2007 feet were inclined plane.

The necessity of making the inclines straight, the extreme steepness of the mountain side, requiring expensive retaining walls, and the depth and frequency of the abrupt gorges and water courses which serrate the Allegheny Mountains, made the location one of great difficulty. The summit was passed at Blair's Gap, through an open cut of 12 feet, and the road descended by three inclined planes, not far apart, into the valley of the Conemaugh, overcoming in 13½ miles 1706 feet of ascent and descent. The mountain branches of the stream were crossed by cut stone viaducts of remarkably good design and construction, the most notable of which was the Conemaugh Viaduct of 80 feet span and 30 feet from foundation to springing line, the whole height of the structure being 85 feet. It was built of cut stone and served its purpose as a railway viaduct for double track, until destroyed by the Johnstown flood in 1889. The cause of its failure appeared to be that the foundation of one of the abutments was upon a timber platform instead of being carried down to rock, which, in that day, with few appliances for reaching rock at anything but a moderate depth, appeared to the engineers to be a difficult undertaking.

On the levels, extending from plane to plane, the superstructure of this early railroad work was formed of malleable parallel edge rails, weighing 39½ pounds to the yard, with a head 2¼ inches wide and a depth of 2½ inches. These were supported by cast iron chairs,

weighing 12¼ pounds each, placed three feet from center to center. Wherever the solidity of the road allowed a permanent way to be laid the chairs were fastened upon stone blocks, 1 foot thick and 24 inches long, and 21 inches broad, which were firmly embedded in trenches of stone, 1 foot deeper than the bottom of the blocks, and thoroughly drained. The roadbed was of broken stone, 6 inches thick. In through cuts, there were underground catch-water drains to receive the water which percolated through the trenches. On embankments the cast iron chairs were fastened in the first instance to cross-pieces of timber, 8 inches long, which were notched into continuous sills, laid under the line of each rail, these sills being 10 inches square. On the inclined planes the rails were of timber, 6 inches by 8 inches, with plate rails 2¼ inches by 5 inches, and these wooden rails were supported by cross-pieces of the same dimensions, 8 feet long and 4 feet from center to center.

The stone blocks used on the Allegheny Portage Railroad in 1834 had a very short life. They answered the purpose for the first locomotive engines, which were of 4½ tons, and not exceeding 6 tons weight; but when heavier locomotives were brought into use the tracks on straight lines were spread, and where long blocks of stone, extending across the track in curves had been introduced, alternating with the single blocks, they were soon broken, and cross-ties of locust were substituted. At length more and more cross-ties were found necessary, until the stone blocks were entirely removed. This happened as early as 1836–'37.

The inclined planes were operated by stationary, double-cylinder, high-pressure engines of 35 horse-power each, operating drums on which endless ropes of 6¼ to 7 inches circumference were used. The machinery was designed and the construction of the planes supervised by Edward Miller, a civil engineer of Philadelphia, who also designed and put into use the safety cars attached to the planes to prevent accident.

Little need be said in description of the Western Division, commencing at Johnstown, and extending to the city of Pittsburg, except that the greater part of the distance was in canal, of dimensions the same as on the Juniata Division. A considerable part of the line, through the mountain region, presented to the engineer unusual difficulties of construction. There were two tunnels, one 819 feet in length, through Grant's Hill, Pittsburg, and one 817 feet, made to avoid an elbow in the Conemaugh River; and these were among

the early tunnels of the State. Nathan S. Roberts was the engineer of the Pittsburg section, including the Grant's Hill Tunnel. Alonzo Livermore was the engineer of the middle section, including the Conemaugh Tunnel.

The entire line of State works was finally completed on the 10th of December, 1830, under Sylvester Welsh, who was appointed Chief Engineer in 1829, and packet boats passed through to Pittsburg.

It was to provide for the transportation of freight by way of the Pennsylvania Canal and the Allegheny Portage Railroad, without breaking bulk, that Canvass White, civil engineer, suggested the idea of building canal-boats in sections, divided transversely, and placing the sections, or boxes, upon railroad trucks for the passage over the Columbia and Philadelphia Railroad, and over the Allegheny Mountains. These section boats came into common use and played an important part in canal and railway transportation between Philadelphia and Pittsburg. The four sections of a boat, when placed upon trucks, answered the same purpose as the modern box car, and were equally adapted to navigation on the canals and to traction on the railroads.

The theory was that the State should furnish the roadway, and that any one might furnish his own vehicle and motive power and use the railway whenever he pleased, by paying the State tolls. But it was soon discovered that a certain standard of vehicles was necessary, and rules as to the use of the railway were necessary, in order to have it successfully operated. The ordinary shipper found that he could get his transportation done by large and well-equipped shippers at less than he could do it himself, so that the business of transportation drifted into the hands of a few individuals and companies, who performed this service at fixed rates.

Among the rules adopted by the Canal Commissioners for the regulation of railway traffic was one, that no car should carry a greater load than three tons on the Columbia and Philadelphia Railroad, nor more than three and one-half tons on the Allegheny Portage Railroad, nor should any car travel at a greater speed over bridges than five miles per hour, unless the car bodies could be supported on steel springs.

Time will not permit me to enter into any detailed description of the works of the Monongahela Navigation Company, incorporated by the Legislature on the 24th day of March, 1817, and built and operated successfully as a slackwater navigation until the year 1897, when the United States Government assumed possession; nor of the works of

the Lehigh Coal and Navigation Company, which was organized on the 13th of February, 1822; nor of the Delaware and Hudson Canal Company, organized in 1825, whose canal, crossing the northeastern section of the State, connected the Lackawaxen River with the Hudson. The engineers and their co-workers, among whom were Thomas Baird of Pittsburg on the Monongahela, Josiah White and Erskine Hazard on the Lehigh, and Maurice Wurtz on the Lackawaxen, were pioneers in their work of developing the mining of anthracite coal in the State of Pennsylvania, and are deserving of a place in history.

I have called your attention to these early works in Pennsylvania, sensible of the fact that much of what I have written has heretofore appeared in one form or another, but nevertheless with the feeling that many in our circle of the Engineers' Club of Philadelphia have profited by the experience of their designers in the building of other and greater works, better adapted to the requirements of our time. In this we have had the advantage of educational facilities, which our predecessors did not enjoy, and the use of appliances of which they did not dream.

The engineer of to-day, who is accustomed to machinery of all kinds for making his work easy, such as centrifugal pumps, air compressors, hoisting engines, conveyors, and to the use of high explosives; whose work is made accessible by multiplied lines of transit from one part of the country to another, can appreciate the hardships which were undergone by the early civil engineers of the State, in a region of country, as described by one of the pioneers, "clothed with dense forests, and destitute alike of roads, houses and inhabitants, where we were compelled to give up our tents, as pack horses formed our only means of conveyance, and to construct rude huts of hemlock bark and boughs to protect us from the weather; while at times our only dependence for food was upon the success of the hunters accompanying our corps."

The greater number of these men were engineers by instinct and self-training. They had "the art of directing the great sources of power in nature for the use and convenience of man," and therefore were capable of designing and directing engineering work on a moderate scale, and as far as it was possible to do so, while depending on empirical rules and their own limited experience and without modern machinery.

Viewed in this light, the early works of the State were great works; and it was not until after man had learned "to manufacture power,"

and modern machinery following the invention of the steam-engine, and the locomotive had come into use, enabling the engineer to do more work and to move greater weights, that the early constructions were replaced by greater ones.

The first quarter of the last century affords a fair illustration of the work of the civil engineer, dependent, in a large measure, upon his own resources, in the creation of lines of transportation to be operated by animal power alone.

In the second and third quarters the mechanical engineer added steam machinery, with its multiplied adjuncts; in the fourth quarter came the electrical engineer; and with these, and as an aid to all, the discoveries of the chemist, the metallurgist, and the scientist of whatever name, to round out the nineteenth century of progress in the world's history, and to usher in the twentieth, which will develop untold wonders in engineering.

The call is more and more for educated men in all professions, and in none more so than our own. The engineer of the future will need to be well grounded and trained in the natural sciences, and full of resources in using them in the execution of his work. There will be, as the years go by, an enlarged field of usefulness for the exercise of his abilities in designing and constructing, as the now almost unknown countries of the world are opened up to him; and Thomas Tredgold's definition of civil engineering may have added to it one more word, and may come to be known as "the art of directing the great sources of power in nature for the use and convenience and comfort of man."

Let us strive to keep it, with its branches and specialties, as one profession, lofty in its aims, because doing its best work for the advancement of civilization and the betterment of mankind the world over.

# THE CEMENT AGE: THE MANY NEW USES AND INCREASING DEMAND FOR PLASTIC MATERIALS.

A Topical Discussion, November 21, 1903.

R. W. LESLEY.

I AM very glad of the introduction by our worthy President, inasmuch as he says this is a topical discussion and to be opened by myself. I understand that I am to say two words, and the other ninety-eight are to be said by the other members of this distinguished assemblage; so I trust I will not take up much time. The thought that I want to draw to the attention of all those present is that this is certainly the age of the plastic material, and if we go back to history it appears that there was an age of stone, an age of copper, an age of iron, and an age of steel; that all those materials were permanent and fixed in their form and in their character and were not susceptible of much change. It seems almost a philosophical thought that in this age, when man changes and thought changes so quickly, the material representing the period is of a plastic and flexible nature. Being interested in one branch of this flexible or plastic material, my thought was to say a few words about that, but before doing it I want to call your attention to the fact that this is not the only important material of this class. We all remember in our own time the cobble stones that made the paving of Philadelphia. It was impossible to go over them, and when anybody was sick in the house it was necessary to cover the streets with various materials to deaden the sound, and it was impossible to have illness in the house without having the patient threatened with nervous prostration by reason of the noise. All that is changed by the plastic paving material. The asphalt that goes on the street is noiseless and reduces the expenditure of tractive power to a degree that none of us can realize, and has increased the comfort of the community to a point that we can hardly imagine. That is one of the groups of plastic materials that occupies a very important field, but we seldom consider how important these materials are to our comfort and how important to our invalids.

In addition to this field of plastic materials, we have the plasters—

an enormous field that has opened up in the decoration of buildings, in making possible those wonderful expositions that are taking place all over the world. The Paris Exposition, the Chicago Exposition, the Buffalo Exposition, the Charleston Exposition, and the great exposition that is to take place in Saint Louis would be almost absolutely impossible without the plastic material that is used and gives them a wonderful beauty that takes us back from a period of activity and bustle to the days of the ancients, giving the forms of beauty and the spirit of antiquity and charm. So far, therefore, in the age of the plastic material we have the comfort and the increased tractive power in the streets, and we have the beauty and the development that come with these great expositions all over the world. Going back to the branch of the plastic materials that I am more intimately associated with, my purpose is to tell you a little about what we are really doing in cement and about the many new uses of that material.

The growth of the cement industry in the last twenty years is almost surprising. It is hard to believe. The increase in its use can be most readily realized by considering some figures which appear in the "Mineral Industry" and in other publications of the Geological Survey. In 1882 we made 17,000 tons of Portland cement in this country and about a million tons of natural cement, and we imported about 74,000 tons of Portland cement, or a total of a little over one million tons. In that year the total output of pig-iron was about five million tons. The total tonnage of Portland cement in 1902 was greater than the total tonnage of pig-iron in 1882, the figures being six millions, as against five millions, and the growth being from one million barrels to twenty million barrels in the twenty years between 1882 to 1902, as against the growth of five million tons to nineteen million tons for pig-iron. More marvelous is the growth in the per capita consumption of cement in the United States. In connection with this thought there is the larger thought that this country is growing in permanent works, and cement represents essentially this permanent growth. While iron and steel construction, in the shape of bridges and buildings, is always a factor of doubt by rust disintegration, and, as we all know, in the case of pipes and conduits, always a diminishing quantity in their carrying capacity, cement is always a plus factor in its growth, as it tends to gain in strength for periods up to ten, twenty, and thirty years; and no man has yet tested for a longer period without showing always a plus factor. Therefore, when we

state what this country consumes per capita it means that the country is no longer young, but is becoming old, and that we are building bridges, pavements, streets, and sewers all of concrete character, to endure for all time, discarding the flimsy timber construction of the past. In 1850, when this country was in its early days, every citizen took home with him from market at the end of the year a little over six pounds of cement. Along in 1860, just before the opening of the Civil War, we were struggling along with about ten pounds. In 1870, after the war, we carried home twelve pounds of cement in the market basket. In 1880 we had gone through the panic of the Northern Pacific and did not increase very much—only thirteen pounds. In 1890 it took thirteen pounds of cement to carry the family through for the year. In 1890, after going through the panic and again re-establishing financial conditions, the people wanting permanent improvements, we required nearly thirty-four pounds of cement per inhabitant in the United States. In 1900 the figure had increased to ninety-one pounds; and in 1902, from the latest estimate of the population, it takes 119 pounds for every inhabitant of the United States, or about a third of a barrel to get along during the course of the year. These figures simply show that this country is developing in permanent improvements and structures. Taking the figures of growth from the period of 1894 to 1902, the consumption and growth show that this industry has increased 2600 per cent. in less than eight years. During the same period, for purposes of comparison, pig-iron shows an increase of ninety per cent. These figures are almost surprising, and I will be frank to say were surprising to me when first produced, and I speak from pretty long experience in this industry. The total consumption in 1902 of all kinds of cement, natural and Portland, runs close up to 30 millions of barrels. That was a pretty good year in 1902, and the Cement Manufacturers' Association, of which I am the proud President, has come to the conclusion that perhaps we manufacture more material than the market is going to take; therefore we looked around to see what outlet all this cement that we were making was going to find. In going over this question, for my own satisfaction, I have found a number of interesting points that I want to bring before you to-night. The situation is a little like this: here is a great industry that has grown by leaps and bounds—almost beyond the conception of man. I find we have had strikes in the building trades, and we have had all kinds of troubles where people have agreed to buy cement and have not taken it, and we want to look for as many new uses and outlets

to take this great product as we can find. When that subject was brought before me, I took a great deal of trouble to go over all possible fields in which cement can be used, and I want to say that there is hardly a field between the baptism and the grave where some of us do not use cement.

In 1896 I went to Europe to make a study of the methods of construction used there, and I found that there were four or five different companies in France which were constructing large buildings of concrete, including the carrying members, the floors, etc.; and by the addition of small bits of iron in the shape of rods of various designs, they were doing with cement what our iron and steel people were doing in this country with iron and steel. That seemed to offer quite a field, and I went over there and met these people and studied their methods. Without taking up your time explaining how the new use of cement in this field alone has grown, I might mention that there are at least thirty different forms of construction for large cement buildings, as given in the following list:

ARMORED CONCRETE, REINFORCED SYSTEM.

| Name. | |
|---|---|
| Monier ..... | |
| Rabitz ..... | Thin wires interlaced in zigzag form. |
| Kornen ..... | |
| Donath ..... | Wire netting is suspended under carrying and distributing rods. |
| Müller ..... | Somewhat similar to above. |
| Lilienthal.... | Wooden beams are covered with waterproof paper, then wire netting on which mortar is deposited. |
| Stolte ..... | Band iron imbedded in lower part of tiles. |
| Habrich ..... | Twisted steel bars, but no distributing rods. |
| Wünsch..... | Light T-irons as carrying rods, but no distributing rods. |
| Wilson ..... | Curved armatures. |
| Bramick. .... | Used where it is required to support pipes in a floor |
| Expanded Metal ..... | Sheet steel is slit open and then drawn sideways. |
| Columbian Fireproof .. | Ribbed bars are introduced as strengthening members. |
| Roebling ..... | A series of flat bars is introduced and set on edge. |
| Schillinger ... | Combination of chains. |
| Weber ..... | Introduces a metal clamp, fastening together the carrying and distributing members. |
| Hennebigue.. | Reinforcing rods provided with stirrups, the other rods being bent in a truss form. |
| Golding..... | Arched beams. |
| Bordenave ... | Application of ferro-concrete for water-pipes. |
| Bouna ..... | Cross form for armature. |
| Chassin ..... | Combines Monier, Bordenave, and Bouna systems. |
| Giros and Locheurs . | Pipes in short lengths, varying the rise of the spirals or lattices used for carrying rods with the pressure head encountered. |
| Visintini .... | Constructs floors of tiles in form of lattice trusses or girders, in which top and bottom chords are built of mortar. |
| Ferroinclave.. | Corrugated sheets bent back on themselves. |
| Siegwart ..... | Square hollow beams, located at top and bottom chords, top and bottom plates having no armature. |
| Melber ..... | Consists in locating the armature. |
| Ransome ..... | Twisted square bars for carrying rods. |
| De Valliere .. | |
| Thatcher..... | Fortifies strengthening bars by rivets with cupped edges placed at intervals. |
| Hyate. ..... | Horizontal steel bars on edge, pierced by round iron rods. |

Each of these systems supplies business for a separate company, each doing work in the building of large structures, such as houses, mills, factories, and other buildings up to eight and ten stories, out of this material, which six years ago nobody thought was adapted to any purpose other than the building of bridges, sewers, and works of a lower level. It is needless to take up your time explaining how these processes are differentiated. Some of them involve very little the use of beams; in some the T section is largely used, and in others chains or rib bars are employed, as is also expanded metal, through which the cement is forced on the inner side; and every one of these different systems has its organization, with its officers seeking business, and all using iron or steel in connection with cement.

I hope when this topical discussion is started that each of you will give me a new use and find some more purposes to which this new material can be placed; but in order to describe some of these uses I went over all the different advertisements, and all the different pamphlets, and all the different things I had heard, and I divided its uses into a number of different subjects, all of which you are familiar with. Considering railroads alone: The railroad cannot get along without cement; that is assured. They used to try bricks, iron, sand, and other materials, but when they came to building these big railroads they could not get along without cement. A few railroad stations are being built of concrete, and as wood is getting scarce the same material is being used for ties on some of the Western railroads. They use cement floors in their stations because they find it is the only thing that stands the tramp, tramp, tramp, of the passengers; cement gutters; cement curb walks, cement retaining walls, cement round-houses, cement mile-posts. The agriculturalist has cement fence-posts, concrete bins for grain, concrete floors, troughs, reservoirs, and walls. Concrete is used for factory buildings which are on concrete foundations, and they have concrete pillars, when necessary to support the foundations. It is needless to state that when you come to a great city like ours you necessarily meet this material. You see cement sidewalks in front of the buildings. The sewers, gutters, and curbs are of concrete. You know you have concrete bridges all over the city; reservoirs made of concrete; water-towers and water-pipes of the same material; large skyscrapers eight and ten stories high all made of cement and concrete. In modern warfare our ships are lined with concrete to prevent them from sinking when the steel shell is pierced. A vessel coming up in a flood in the Delaware some years ago had its steel hull all cut to pieces, but

good Portland cement concrete under the flimsy steel, landed the vessel safely in port. Even to meet the storms of the sea, the waves and the dashing of the element, when you come to build a lighthouse it is built of cement. When you come to build a sea wall, it is built of cement. In Chicago, to prevent the encroachments of the Lake they went so far as to make a concrete beach slope down, so that the waves would dash upon it and it would remain for all time. In mining, the timbers are being displaced by concrete piers. In the lining of petroleum wells concrete is used, and also in coal-mines. I have already spoken of the ornamental uses of cement, but I did not have slides prepared to show them. By a most ingenious scheme of pouring cement into damp sand, in a method analogous to the making of cast-iron, the most beautiful effects in sculpture are produced in concrete, and Mr. Mercer at Doylestown, is now reproducing garden works and the statuary of Rome and Greece in the colors, form, and outline of this material, colored in the most beautiful way and giving the most artistic effects and at an expenditure absolutely insignificant as compared with stone; so that without going into any definite description of all these many uses, some 100 or 150 in number, that I have assembled here, for all of which I have a description and for all of which I could give you the details, I only want to say in opening this discussion that this material has numbers of uses that I doubt if any of us here were ever familiar with until brought suddenly face to face with them.

USES OF CEMENT.

RAILROADS.

Concrete Arches.
" Bridges.
" Subways.
" Railway Stations.
" Ties.
" Telegraph Poles.
" Tunnels.
" Telephone Conduits.
" Curb Walks.
" Retaining Walls
" Girders.
Cement Floors.
" Gutters.
" Round-houses.
" Butts for telegraph poles.
" Clinker Pits.
" Transfer Pits.
" Turn-tables.
" Culverts.

FARMING.

Cement Fence-posts.
" Vine props.
Concrete Bins.
" Troughs.
" Pig-pens.
" Hitching-posts.
" Floors for Stalls.
" Reservoirs.
" Sluices, as protection against freshets.
Cement flumes for irrigation.
" Joints in drains.

FACTORIES.

Concrete Buildings.
" Piles for support.
" Hopper Bins.
" Boiler Settings.
Cement Pipe Coatings.
" Gas Purifiers.
" Coating in Vaults of Breweries.
" Storage Bins.
" Chimney Stacks.
" Reservoirs.
" Storage Tanks.
" Cellars.

USES OF CEMENT—(*Continued*).

DWELLINGS.

Hollow Block and poured cement houses.
Cement Floors.
" Terraces.
" Stairways.
" Ornamentation.
" Roofs.
Cementine Curtains.
Cement Storage Vaults.
" Laboratories.
" and sawdust Tiles.
" Table-tops.
" Paint (for corrosion).

MUNICIPAL.

Cement Sidewalks.
" Sewers.
" Bulkheads for Dams.
" Locks.
" Canals.
Combined curb and gutter.
Cement Dams.
Concrete Bridges, Aqueducts, and Jetties.
" Flags.
" Filters and Reservoirs.
" Water Towers.
" Fence-posts and Conduits.
" Joints.
" Crevice-filler.
" Pipes for Water-main.
Cement Cable-canal.
Foundation for Streets.

BUILDINGS.

Churches.
Show Buildings.
Jail Corridors.
Skyscrapers.
Cement Vaulting.
Grain Elevators.
Banks.

RECREATION.

Grand Stand (Base-ball Park, Cin., O.).
Fraternity House (Yale).
Foundation for Bowling-alleys.
Tennis-courts.
Speedways.
Racket-courts.
Swimming-pools.

MARINE.

Ballast-tanks in Warships.
Quicksands.
Lighthouses and Sea-walls.
Concrete Beaches.
Docks and Piers.
Breakwaters.
Forts and Batteries.
Gun Emplacements.
Naval Stations.
Boats, in which planks are made of armored concrete.

MINING.

Mine Timbers.
Cementing of Petroleum Wells.
Cement in Salt-mines.
Cement Coal.
Bricks.

ORNAMENTAL.

Tombstones.
Burial Vaults and Caskets.
Ware products.
Panels, Brackets, Keys.
Columns.
Capitals.
Pilasters, Moulding, Veneering.
Fountains.
Sun-dials.
Street Monuments, Statuary.

It is certainly an age of plastic material, of this permanent, enduring, constantly gaining material, a material that is adapted to artistic work and to work of the simplest character—a material that can be used in the most decorative way, and a material that can be used in the strongest and most substantial structures. In opening the discussion to-night I have only outlined in a very brief way these numberless purposes, and no doubt out of the opening of this dis-

cussion, the very few uses that I have suggested and the very few uses that I have been able to gather, the details of which I have here but do not want to take up your time to discuss, will elicit from the members of this society thoughts and ideas extending beyond any that have hitherto been expressed. As I have already said, cement is one of those substances to whose uses we have suddenly awakened, and these new uses are coming before us at every turn.

## GENERAL DISCUSSION.

The President.—I think we shall be forced to admit, after hearing the many new uses, mentioned by Mr. Lesley, to which cement and concrete are put, that this is, indeed, the cement age. I hope that among our members there will be a free discussion of this topic, and that Mr. Lesley may be so fortunate as to have mentioned to him a few more uses for cement. He may not have exhausted the list.

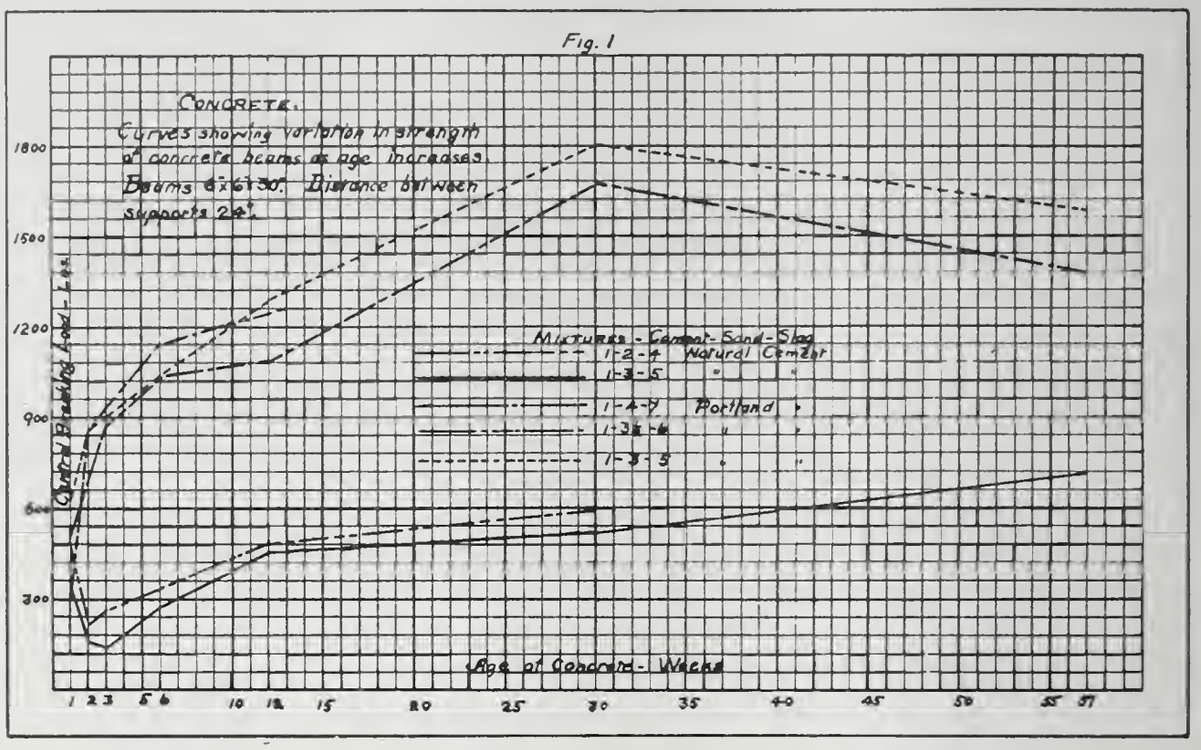
Henry Leffmann.—The list of plastic materials might be increased by the addition of rubber, which has entered very largely into certain phases of modern life. I did not notice that Mr. Lesley referred to tombstones; there is a demand for these, and a very excellent article might be made with cement. It also occurs to me that a large demand for concrete will probably arise in connection with the construction of the Panama Canal, but I do not know the details of the engineering work. Something pretty strong, stout, and heavy will be wanted. Our knowledge of the population of that region leads us to suspect that they may not be very friendly, and something difficult to deal with should be used. If the development in transportation methods in cities goes on very rapidly in the direction in which it seems to be going now, it will not be long before asphalt paving will disappear and concrete paving take its place. My notion of the ideal city is one into which no horse would ever come, all the street traffic being conducted by motor vehicles. Under these conditions we would not need a railway in the street; the car would simply run along the smooth surface of concrete. The footwalk would be a line of different level, but the material would be but little subject to wear, and traffic would be very satisfactory. I anticipate, therefore, that in the horseless age the demand for concrete will be much increased, and that for asphalt very much diminished.

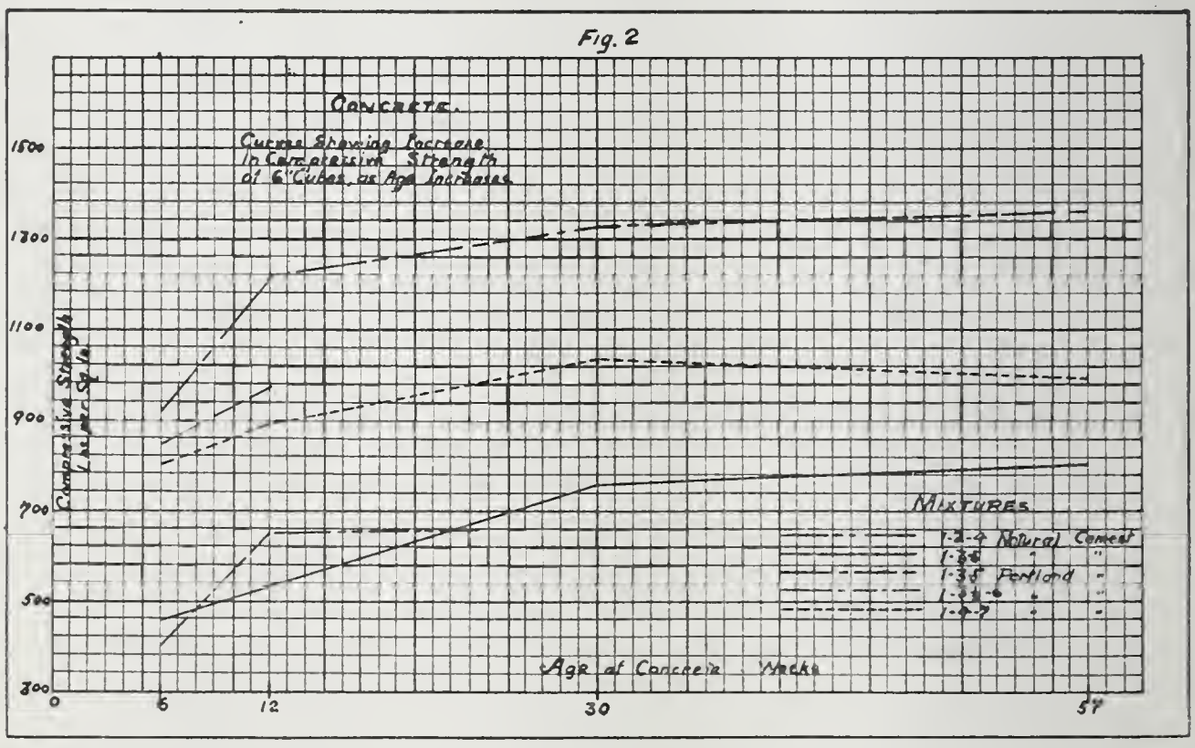
James Christie.—The company which I represent has been using concrete extensively for several years, as a substitute for brick in the walls of iron frame buildings, and latterly have been applying it for floors with steel reinforcement. For the walls of buildings, it suits admirably as a diagonal bracing, and connection fittings, which interfere with the use of brick, act as an excellent reinforcement for the concrete. Some time ago, feeling the need of more definite information regarding the strength and general resistance of various mixtures of concrete, we inaugurated a series of experiments on concrete beams. We adopted a standard specimen, six inches square and thirty inches long. These were tested transversely, with the load central between supports twenty-four inches apart. The experiments covered an interval of about one year, and included a variety of mixtures and proportions, using both natural and Port-

| Brand of Cement. | Proportions by Volume. | | | Breaking Load at Center (Pounds). Age in Weeks. | | | | | | | Moduli of Rupture. Pounds per Square Inch. Age in Weeks. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cement. | Sand. | Slag. | 1 | 2 | 3 | 6 | 12 | 30 | 57 | 1 | 2 | 3 | 6 | 12 | 30 | 57 |
| Improved Union . . | 1 | 2 | 4 | 471 | 220 | 270 | 351 | 485 | 597 | | 73.5 | 36.6 | 45.0 | 58.5 | 80.8 | 99.5 | |
| Improved Union . . | 1 | 3 | 5 | 350 | 161 | 147 | 279 | 466 | 515 | 717. | 56.3 | 27.0 | 24.5 | 46.5 | 77.7 | 85.8 | 119.6 |
| Vulcanite Portland | 1 | 4 | 7 | 511 | 708 | 877 | 1039 | 1094 | 1680 | 1378 | 85.2 | 118.0 | 146 | 173 | 182 | 280 | 194 |
| Vulcanite Portland | 1 | 3½ | 6 | 314 | 862 | 919 | 1148 | 1248 | | | 52.3 | 144 | 158 | 179 | 208 | | |
| Vulcanite Portland | 1 | 3 | 5 | 611 | 667 | 901 | 1152 | 1293 | 1803 | 1588 | 102 | 111 | 150 | 192 | 216 | 300 | 264 |

land cements. A summary of these tests is embraced in a paper and tables by Mr. A. P. Hume.

A. P. Hume (Communicated).—A brief account of some tests, with which I was concerned, on the strength and fire-resisting qualities of concretes, may be of interest, in connection with the question under discussion.




A transverse statie test was made with the primary object of comparing the strengths of various concrete mixtures of a Portland and a natural cement each of which was being quite extensively used. Concretes of blast-furnace slag and elean river-sand, with each of the two cements, were made into test blocks 6 inches by 6 inches by 30 inches; which were removed from the moulds forty-

eight hours after mixing and allowed to dry in the air until of proper age for testing. They were then tested on half-round supports, with a central load applied across the whole width. It was found that after an age of six weeks, the ends of the blocks broken in test were uninjured, and these were, thereafter, carefully dressed into 6-inch cubes and tested for compressive strength. The proportions of the various mixtures and results obtained from tests are shown on page 99. Figures 1 and 2 show curves plotted from these results, each value being the average of results obtained from two to four similar blocks.

The most noticeable peculiarity in the curves for transverse static strength is the marked decrease in strength of the natural cement concretes at early ages. As the points on each of these two curves that fall below the strengths at one week are based on tests on nine separate blocks, making eighteen blocks in all, showing decreased strength, the fact seems well established that an actual loss of strength occurred. It was observed at the time of testing that the natural cement concretes, one week old, did not break as readily in handling as similar blocks a few weeks older.

| Mixture, Parts by Volume. | | | Size of Cubes (Inches). | Treatment. | | Compressive Strength (Pounds per Square Foot). | Decrease in Strength (Per Cent.). |
|---|---|---|---|---|---|---|---|
| Cement. | Sand. | Slag. | | Temperature to which Heated. | Manner of Cooling. | | |
| 1 | 3 | 5 | 6 | Not heated. | | 168,600 | |
| | | | | 1000° F. | In air. | 145,200 | 13.8 |
| | | | | 1000° F. | Quenched. | 135,800 | 19.4 |
| 1 | 3 | 5 | 8 | Not heated. | | 180,500 | |
| | | | | 1400° F. | In air. | 141,500 | 21.6 |
| | | | | 1400° F. | Quenched. | 115,600 | 35.8 |
| | | | | 1500° F. | Quenched. | 81,000 | 55.0 |
| 1 | 2 | 4 | 8 | Not heated. | | 208,700 | |
| | | | | 1500° F. | In air. | 137,600 | 24.0 |
| | | | | 1500° F. | Quenched. | 95,460 | 54.1 |
| 1 | 4 | 7 | 8 | Not heated. | | 92,600 | |
| | | | | 1600° F. | In air. | 77,500 | 18.8 |
| | | | | 1600° F. | Quenched. | 55,300 | 40.3 |

The decrease in strength of the Portland cement mixtures cannot be regarded as being as positively established as that for the natural cement mixtures, since the points for the thirtieth and fifty-seventh weeks are based on only two blocks in each case. In view of the comparatively few individual tests determining this decrease, it may in part be due to the same causes producing the well-known marked differences in tests of briquettes, though prepared from the same cement and under apparently identical conditions. A uniform approach of the natural cement mixtures to the strength of the Portland concretes is clearly indicated, and whether or not an actual equality is eventually reached, it seems clear that

the latter is better fitted for operations in which it is necessary to load the concrete constructions within a short time of laying.

For experiments on the fire-resisting qualities of concrete, 6-inch and 8-inch cubes were prepared from a Portland cement mixed in the same manner as for the above-mentioned transverse static test. These were placed in a furnace and completely surrounded with flame for periods varying from one-half to one hour, or until uniformly heated throughout. When at the desired temperatures, as shown by an electric pyrometer, they were removed, some being allowed to cool in the air, and the others being thoroughly wetted or quenched by a stream of water from a hose. The table on page 101 gives data obtained from the compressive test of these blocks:

A marked decrease in compressive strength occurred, being greater, the higher the temperature, and blocks drenched with water while hot show a still greater decrease. All of the blocks, after removal from the furnace and after quenching, retained their original forms, but were evidently less coherent than before, and corners and edges could be easily broken off with the fingers, more so with the quenched than with the air-cooled blocks. A few minute cracks could be detected, on close examination, in the more highly heated cases. It was noticeable that fragments from the compressive tests on quenched blocks were more readily pulverized than those from air-cooled blocks.

Experiments were made on briquettes of various Portland cements and one natural cement, both neat and 1 to 1 mixtures, prepared in the standard manner. One-half of each briquette was heated to a temperature of 1600° F. and the other half preserved in its natural state. The considerable loss in compressive strength that occurred upon heating is shown below, though since each value is the result of only one test, no positive conclusions can be drawn as to the relative heat-resisting qualities of the various brands:

| Kind of Cement. | Composition. | Compressive Strength Unheated (Pounds per Square Inch). | Compressive Strength after Heating (Pounds per Square Inch). | Decrease in Strength from Heating (Per Cent.). | Age of Briquettes (Months). |
|---|---|---|---|---|---|
| Portland A.. | Neat. | 10,280 | 6,490 | 36.9 | 13 |
| Natural B.. | Neat. | 4,490 | 1,460 | 67.5 | 20 |
| Portland C.. | Neat. | 10,630 | 3,360 | 68.4 | 20 |
| Portland D.. | Neat. | 3,260 | 1,410 | 56.8 | 9 |
| Portland E.. | Cement 1, sand 1. | 6,080 | 1,850 | 69.6 | 20 |
| Portland D.. | Cement 1, sand 1. | 1,270 | 254 | 80.0 | 7 |
| Portland A.. | Cement 1, sand 1. | 3,600 | 1,950 | 45.8 | 12 |
| Portland C.. | Cement 1, sand 1. | 1,110 | 550 | 50.8 | 8 |
| Portland F.. | Cement 1, sand 1. | 1,060 | 590 | 44.3 | 7 |

Experiments were also conducted on a form of roofing tile, made of sand, gravel, and Portland cement concrete. It was about 26 inches by 48 inches in length and breadth and $\frac{7}{8}$ of an inch in thickness, with a sheet of expended metal imbedded near its under surface. One of these tiles was heated over a fire with a temperature of from 1600° to 1800° F. for an hour, and was then thoroughly drenched on its upper surface with water. In spite of the hot fire

underneath, radiation from the upper surface was so effective that this surface did not rise above 800° or 1000° F.

A comparison of the concentrated loads carried by two similar tiles, one heated as described, and one in its natural state, is shown in the following table:

| Unheated Tile. | | Heated Tile. | |
|---|---|---|---|
| Load (Pounds). | Deflection (Inches). | Load (Pounds). | Deflection (Inches). |
| 106 | .020 | 79 | .063 |
| 206 | .075 | 104 | .156 |
| 306 | .136 | 129 | .219 |
| 406 | .223 | 154 | .438 |
| 506 | .405 | 179 | .594 |
| 636 | Broke. | 244 | Broke. |

The tiles were supported for test on knife-edges, and the concentrated central load applied over the whole width. About 60 per cent. of its strength was lost owing to being heated.

James Christie.—So far as observed, there is no limit to the gradual and constant increase in the strength of the concrete made with natural cement. On the other hand, a fall of strength, after a certain period, is denoted for the concrete made with Portland cement. It may be that the number of aged specimens of the latter material were too few to draw any fixed conclusion from. Attention is also directed to the invariable drop in the natural cement concrete at an early period of its age, this loss, however, being always fully restored. The loss in strength by exposure to high temperature confirms the results obtained from other experiments.

Richard L. Humphrey.—I would state, Mr. President, in explanation of the behavior of the natural cements as indicated in the diagrams shown by Mr. Christie, that there seems to be no law governing the hardening of cements when preserved in air. This seems to be particularly true of natural cements. This class of material acquires hardness very slowly. There seems to be an incomplete formation of compounds of lime, and the silicates of lime crystallize much more slowly in the natural cement. In Portland cements, on the contrary, the proportioning of the ingredients is much more careful, the burning is more thorough, the resulting combinations of the lime, silica, and alumina are more complete, and the extremely fine pulverization of the clinker considerably accelerates the formation of the silicates and aluminates of lime.

The characteristics of these two classes of cement, when tested with mixtures of sand and stone in compression, are a very slow development of strength in the case of the natural cement, and a more rapid growth in the case of Portland cement; natural cement during the early stages of hardening possessing a very low strength up to six or more months. I think, therefore, that the drop in the curves in the diagrams exhibited by Mr. Christie are accidental, and due, probably, to an insufficient number of test specimens. There would be no reason for the phenomena of this character. The mere drying out of the test specimens would not cause a loss of strength, but would merely check

the rate of increase in the hardening. Lack of uniformity in mixing and moulding these specimens is probably the correct explanation of this drop.

The fact that Portland cement acquires strength much more quickly than natural cement is one of the reasons why it is preferred in engineering construction, because, as a rule, it is necessary to place the maximum load on the structure within a short time after the cement is used, a period entirely insufficient for natural cement to develop sufficient strength. Natural cement mortars and concretes, after one or more years, develop considerable strength and make a tougher material than Portland cement. Laboratory and mortar-box tests of natural and Portland cement mortars show that while the natural cements have much lower strength than Portland cements, during the first year, nevertheless, at the end of that period, they begin to increase rapidly, and after several years the tests often show the natural cement mortars stronger than the Portland cement mortars.

There is, however, a period in the hardening of both of these classes of cement when there is an apparent retrogression. In Portland cement this occurs after one or more months. In natural cements it rarely occurs before several years. The explanation of this phenomenon, I think, is that the hardened material is a crystalline substance. When water is added to the cement, the mass is in an amorphous condition. From this amorphous mass the crystals form and the mass acquires hardness. With the increase in this crystallization the material ceases to be tough and becomes brittle, and eventually reaches a period when the tensile strength shows a falling-off. The material, however, has been steadily increasing in compressive strength, and, in my experience, I have never observed the phenomena shown in the diagrams of Mr. Christie, where cements, either natural or Portland, exhibited a falling-off in compressive strength within the first year of their hardening, and it seems to me that this must be ascribed to the faulty manipulation of the test specimens rather than to the characteristic behavior of the cement.

When cements reach the highly crystalline state to which I have just referred, they become practically stone, and should be submitted to those tests that are customarily applied to stone.

The tensile tests, which we use as a basis for the acceptance or rejection of shipments of cement, are not indicative of the strength of the material. They are merely gauges by which to compare the quality of each shipment.

The requirements of specifications for cement have undergone a change, in the last few years, which is almost parallel to that of steel. When steel was first used in this country, the requirements of specifications rapidly increased until a high-carbon steel of high tensile strength was obtained. This was found to be too hard and brittle for good service, and the sentiment changed to a lower-carbon softer steel, having greater elasticity and a lower tensile strength. So it has been with Portland cements. The demand for great strengths at the seven and twenty-eight day periods is rapidly disappearing, engineers preferring a cement that develops a moderate tensile strength for seven and twenty-eight days and shows a progressive hardening.

In 1892, when I first began to test cement, we were using almost exclusively Portland cements made in set kilns. The burning could not be carried on to the same degree of temperature, nor be as thorough as is the case with the modern rotary kiln, and a class of cements resulted which developed (neat)

hardly more than 450 to 500 pounds in seven days, but which showed a progressive increase in strength up to five or more years. After this period they became quite brittle and showed the characteristic falling-off in tensile strength. This was true not only of foreign, but of domestic cements.

The extremely fine-ground product of the rotary kiln is characteristically quick-hardening, and unless the cement be of very inferior quality, it rarely tests under 600 pounds in seven days. The crystallization in this material is rapid, and the period at which it shows a falling-off in tensile strength occurs usually within six months, and frequently in twenty-eight days. I think, however, that there is no danger to be feared in this peculiar behavior of these cements, for the reason that I have already given, and I think in the use of cement, in reinforced concrete construction, engineers will place very little reliance on the tensile strength of the material.

With reference to the use of reinforced concrete, there is another feature about which I wish to speak. That is the great mass of steel that is imbedded in reinforced concrete, which is far in excess, in many cases, of the requirements. Steel is placed in concrete with the view of taking up whatever tension may come on the structure, and to distribute the tendency to crack from shrinkage, which is characteristic of rich concretes. As an illustration of this feature, I would cite an instance of the concrete steel bridge in Brooylyn, of 85-foot span, the arch being 22 inches thick at the crown and over 2 feet thick at the haunches. Steel rods were put in about 8 inches apart in a double row with a sheer rod running from the upper to the lower. When the steel was all in place, and before any concerte had been deposited, the amount of metal there was so great that it looked as if it might be difficult to deposit the concrete. On looking at this structure my impression was that the arch would have supported itself without any reinforcement whatever, and the great amount of steel which was placed in there was simply wasted metal.

In inspecting concrete steel structures throughout this country I find that the designers, either from a lack of knowledge or from a fear of not getting in enough metal, are prone to place in the work excessive amounts of steel, and I think that the committees on reinforced concrete that are now being appointed have a most excellent opportunity to point out the rational manner in which steel should be used to reinforce concrete constructions—for such structures are essentially concrete structures.

Another feature in concrete construction is the waste of cement. The proportions in the average concrete are entirely too rich, and the result is that shrinkage cracks occur which create false impressions as to the character of the cement. A favorite proportion for concrete is 1, 3, and 6. This proportion was adopted for the materials which were used in the concrete bulkhead along Delaware Avenue in this city (which was started in 1897), and was determined after a careful study of the voids in the material to be used. The same proportions are used for concrete all over the country, and from a personal observation I know that they are thoroughly inconsistent,—in many instances, because the character of the material used is not so proportioned as to properly fill up the voids. The proportions to be used in concrete should be fixed for each piece of work from a determination of the voids in the sand and stone to be used.

In the matter of proportions we are far behind European countries, where

1, 4, and 8, and 1, 8, and 12, are frequently used, proportions which would give the average engineer in this country heart failure. With proportions of this character shrinkage cracks are much less frequent, and are generally distributed by the use of small steel rods.

In the question of rendering concrete impervious, the efforts seem to be directed to so proportioning the concrete as to make it impervious, without regard to the shrinkage which will occur in a mass of the material. The result is that the greatest amount of leakage occurs at the shrinkage cracks. In concrete construction, therefore, provision should be made for expansion and contraction.

In conclusion, I would add that the observations of most engineers on the behavior and characteristics of concrete are based on observations covering short periods of time, rarely extending beyond one year. No intelligent information can be obtained from concrete structures which do not cover a period of four, five, or more years, as it is at the end of these periods that the characteristics or the failures in concrete begin to develop.

R. W. Lesley.—Mr. Chairman, in reply to Mr. Christie and also to Mr. Humphrey, there are two or three things that attract my attention. In the first place, this question between the natural and Portland cement seems to be a case of the tortoise and the hare. To illustrate the proposition we will assume the lower line is the tortoise (referring to diagram on blackboard) and the upper the hare. If you take this and follow it out a little farther, it is easy to see that the tortoise would probably win the race; so it is in the question of a great deal of work where natural cement may be properly substituted for Portland cement. The great engineers of the New York aqueduct system and the Boston Dam have actually built the biggest dams in the world—the Clinton Dam near Boston and the Croton Dam of the Croton Valley—with natural rather than Portland cement, the theory being that there was no immediate great pressure to be brought upon them and that by using natural cement, the weight of the body of masonry could be increased—no great initial tensile strength being required of dams that took ten or twelve years to build—so that while the natural cements are not as good as Portland cements for the purpose of large skyscraper buildings, where weight is superimposed almost day to day, they are in the great bulk of work fully equivalent to Portland cement, because there are no such immediate strains ever imposed upon them, and those lines that Mr. Christie has put on the board (the five-week period) would be almost reproductions of the charts that appear in almost every city engineer's report in the United States; showing the relative results of Portland and natural cements, on mortars of one to three mixtures and one to two mixtures at the end of a year. As Mr. Humphrey has very properly said, the tests applied to cement are tests applied to flexible material, and Portland cement is essentially a non-elastic material. For the purpose of discussion there is a thought that possibly underlies this question, and that is, that the old Portland cements that we made in the dome kilns were cements that remained in the fire for a considerable period of time and did show a constantly increasing curve, and to my own knowledge those cements are still gaining and show no retrogression. My thought is, and I reason not from experience but from observation and possible analogy, that there may be some analogy between the old dome kiln cement—where the powder was made into mud, where the mud remained exposed to the sun and atmosphere or was brought into rooms

and heated and gradually dried, then placed in kilns and remained in the fire for a week or four or five days—that there may be some possible analogy between that and the manufacture of wrought-iron, which is rather a slower process than the manufacture of Bessemer steel, and when we get around to the production of the rotary kiln cement, we are certainly beginning to produce what might represent in the iron and steel industry a much more highly crystallized product than we had heretofore produced; this raw material being produced with the mixture in powder and the product being made very rapidly by the contact of the flame in a few hours. Therefore the same methods would apply to that as would apply to the original testing of Bessemer steel, where every attention was paid to tension and little attention paid to elasticity.

One more thought, possibly in explanation of Mr. Christie's remarks: The natural cements, when pulverized and examined under a microscope, show a flaky substance after grinding, whereas the Portland cement, burned in a revolving kiln, shows a very highly crystallized material. The laying of the flakes, one upon the other, seems to offer a larger substance for continual gain in sand mixtures at long periods than these natural cements show, whereas the crystals of the rotary cement seem to acquire a greater strength at earlier periods. In other words, there is a distinct difference between the crystalline structure of rotary Portland cement, which might represent the highly crystallized Bessemer steel, and the natural cement, which might represent the wrought-iron.

These are the thoughts that strike me in connection with a table like that. (Referring to table on blackboard.) As to the statement that the Portland cements made by the rotary process, do show, by tension tests, retrogression at short periods, it is undoubtedly true, but those same cements in compression certainly show a continual gain and are not of an absolutely non-elastic character. Possibly the best results are at about the center of the course of this pendulum. But there is a tendency among all men always to specify a little above the last specification, so that if the individual who was first among Portland cement manufacturers should go around and feel happy because he could give the engineer three hundred pounds, at seven days, some other person would come along and give four hundred. The fate of the cement man and the iron manufacturer has been like that of the celebrated jumping horse, which started to jump four bars and they kept on raising the bar until he jumped seven feet four. Those who started in this business have gradually raised the limit until we are making seven hundred pounds at seven days, and now we are coming to the other side of the specification. The last specification of the Pennsylvania Railroad requires that the cement shall not exceed 700 pounds, and now that we are leaping a six-or seven-barred fence and are in motion, we wonder how we are going to leap lower.

The President.—I think, gentlemen, the hour for adjournment has about arrived. This has been an interesting evening for us all, and I certainly hope that the discussion may be taken up again at another meeting. I called attention some time ago to the trouble that has arisen of getting our busy members to write papers. I realize that the busy man in this age has little time for anything else than his work. It has become a matter of some inconvenience to our Information Committee to get papers, and so I know of no better way to take up an evening than to discuss a topic. Our time this evening has been well spent. We have heard interesting things and have gained much information on the various uses of cement.

# CONCRETE: ITS PROPERTIES AND APPLICATIONS.

A Topical Discussion, January 2, 1904.

EDGAR MARBURG.

THE interest manifested at a recent meeting of the Club in a discussion on cement and its uses, opened by Mr. R. W. Lesley, suggested to the committee in charge of our meetings the desirability of a continuation of that discussion, in the direction more especially of concrete: its properties and applications.

The introduction of a subject of such magnitude within the brief time at my disposal imposes the necessity of confining the same to a succinct generalization of some of its most important features, in the hope that what I shall say may prove suggestive to others and lead to a general discussion of some interest and value.

The use of concrete formed with a matrix of puzzuolana, lime, and sand dates back to several centuries before the Christian era. It is, however, only within the very recent past, and long after the discovery of our modern Portland cement, that the great value of concrete for innumerable forms of construction received the recognition it now concededly deserves. The enormous increase in the consumption of cement during the past decade has been strikingly presented by Mr. Lesley, and the statistics he adduced may be accepted as fairly illustrative, in a relative sense, of the increasing use of concrete. The favor with which concrete construction has come to be regarded in engineering circles is to be attributed partly to the improved quality and decreased cost of cement, as the difficulties of its manufacture have become more thoroughly mastered; and partly to the increased confidence of engineers in its reliability, as its worth has been proved again and again under new and previously untried conditions. The combination of concrete with steel, in a form variously designated as steel concrete, reinforced, armored, and ferro-concrete, has opened up a vast field of new possibilities, the limits of which are as yet but dimly recognized.

Compared with stone masonry, concrete is not only cheaper, but offers important advantages in speed of construction, and in the fact that it can be laid with unskilled labor. By reason of its monolithic character it is particularly adaptable to foundations, abutments,

retaining walls, and structures in general subjected to unevenly distributed pressures.

As a substitute for structural steel, concrete construction, though frequently, and perhaps usually, more expensive as to initial outlay, is far more durable and economical in point of maintenance, apart from its greater solidity and freedom from vibration.

Other characteristics possessed by concrete in an eminent degree, such as its adaptability to subaqueous construction, impermeability, weathering, and fire-resisting qualities, and the protection afforded to imbedded steel against corrosion, render its use invaluable under suitable conditions.

Let us now consider briefly the more important physical properties of concrete, with the understanding that unless otherwise stated reference is had to well-made and well-seasoned 1:2:4 or 1:2½:5 concrete of good Portland cement, sand, and broken stone.

The compressive strength of concrete as determined by innumerable laboratory tests shows remarkable variations between materials of like age and proportions and kept under similar conditions before testing. The results are affected chiefly by the character of the ingredients, the method of molding and of bedding in the testing machine, the proportion of water used in mixing, and by the size and form of the specimens; and to a less extent by a variety of other influences. Generally speaking, the compressive strength attained at the age of one year may be assumed at from 3000 to 4000 pounds per square inch, about one-third of this strength being developed within a single week and about one-half at the age of one month. The relation between the crushing strength of laboratory specimens and large masses of concrete is of course unknown. That carefully prepared test-pieces are superior to such average samples as might be cut from concrete as laid in actual building operations cannot be doubted. This advantage is neutralized, however, to a considerable though unknown extent from the fact that in large masses the material is relatively better supported laterally against failure. For all ordinary cases a working stress in compression of 400 to 500 pounds per square inch may be safely assumed. This value is about the same as that usually allowed on the best ashlar masonry, although the crushing strength of our common building stones is from one to five times as great as that of well-seasoned concrete. It is well known, however, that the strength of masonry piers is much lower than that of test-pieces made from the same material, owing to the weakening effect of the mortar joints and other influences.

The modulus of rupture of plain concrete in bending is about equal to its tensile strength, and both may be assumed at about one-tenth the strength in compression. A working stress of 50 pounds per square inch may be regarded in most cases as a suitable value.

In the designing of reinforced concrete structures the modulus of elasticity becomes of the utmost importance. Experiments indicate, as might have been anticipated, that its value increases with the age of the concrete and decreases under increments of stress. It is affected also to a considerable extent by the proportions of water used, wet mixtures yielding lower values. For well-seasoned concrete the modulus of elasticity in compression may be safely assumed at 3,000,000, or one-tenth that of steel. The experiments of the Austrian Society of Engineers and Architects indicate, however, that the modulus of elasticity of concrete in large masses is only about one-half that found in small specimen tests. Mr. Edwin Thacher, a leading authority on steel-concrete, accordingly recommends a ratio of one-twentieth between the moduli of concrete and steel.

The weight of experimental data seems to show that the modulus of elasticity of concrete in tension may be properly assumed as equal to that in compression, although in some tests its value was found to be only about one-half as great. The assumption of equal values in tension and compression commonly made in practice is apparently justified, and simplifies the analysis of the stresses in bending.

While the fact is well established that the modulus of elasticity of concrete decreases rapidly under higher loading, the same experiments show that it is sensibly constant up to a crushing stress of at least 1000 pounds per square inch, or considerably beyond the highest allowable working limits, so that the common theory of flexure may be confidently applied to the design of concrete beams, both plain and reinforced. In the analysis of the stresses beyond the elastic limit and up to the moment of rupture the assumption that the intensities of the internal stresses vary as ordinates to parabolic curves having their vertex at the neutral axis is apparently in better agreement with actual conditions.

The adhesive strength of concrete to imbedded steel is also an element of the greatest importance in the strength of such composite material. The comparatively few tests that have been made show a wide range of values. The results are largely affected by the continuity of the bond between the steel and the concrete, and wet mixtures are obviously better calculated to insure perfect contact,

and give, as a matter of fact, higher values. The adhesion of well-made concrete to smooth steel rods may be assumed at about 500 pounds per square inch, although in view of the great variation in experimental data the working stress should be limited to about 50 pounds per square inch, a value equal to that suggested for pure tension. To increase the adhesive shearing strength between steel and concrete various patented bars with lateral protuberances and other devices for strengthening the bond between the two materials have come into successful use.

A remarkable influence on the elastic behavior of concrete produced by imbedded steel to the extent of only one or two per cent. of the cross-section is to be found in the fact that the extensibility of the concrete before rupture is thereby very greatly increased; in certain cases observed by M. Considire, as much as twenty-fold. This peculiar effect, which could hardly have been anticipated, makes it possible to develop stresses in the imbedded steel nearly or quite up to its elastic limit before the concrete itself exhibits evidences of failure.

The relation between the coefficients of expansion of concrete and steel has not yet been adequately determined. Fortunately, such evidence as exists indicates that the expansion and contraction of these two materials under thermal changes is practically the same.

Following this cursory review of the physical properties of concrete, let us consider briefly certain matters of more direct practical interest.

Theoretical discussions as to the relative economy of concrete mixed in varying proportions, based on laboratory results, are often misleading. The judicious blending of carefully assorted material may be easily accomplished in the laboratory, whereas the attempt to conduct similar operations on actual works of construction would prove uneconomical or wholly impracticable.

The assumption frequently made that the most economical mixture is that one which gives the maximum unit strength per unit of cost is also, generally speaking, inadmissible. That mixture is the cheapest which meets given requirements as to strength and other qualities at a minimum cost of material and labor. If, for example, the strength might be doubled at an increased cost of only 25 per cent., the added expense would not be justified if it be certain that the added strength will not be needed.

While it is impracticable to estimate the requirements in any given

case to a nicety, and to proportion the ingredients accordingly, yet, on the other hand, there is no doubt that, either through ignorance or carelessness, certain well-established principles of economy are not infrequently disregarded. Thus, it is manifestly advantageous that the voids in the aggregate shall be reduced to the lowest, easily obtainable limit; not only to save cement, but because the mortar is weaker than the finished concrete, so that a reduction in the proportion of mortar used increases the strength of the concrete, provided the voids are thoroughly filled. Again, experiments show that finely crushed stone is stronger than equal parts of sand, owing to the better adhesion of the cement to the former. The use of unscreened stone, as it comes from the crusher, with only the fine dust removed, is advantageous, therefore: first, by reducing the quantity of cement; second, by reducing the cost of the stone; and third, by increasing the strength of the concrete.

The proportions of voids in broken stone of uniform size vary, usually from 45 to 50 per cent. independent of size, whereas the voids in unscreened stone are from one-tenth to one-fourth less.

That specifications for concrete are apt to be loosely or ambiguously worded is a well-known fact. The usual statement, for example, that Portland cement, sand, and broken stone shall be mixed in certain parts is comparatively meaningless unless the manner in which these parts shall be measured is definitely prescribed. Thus, the volume of a given quantity of cement in a loose state compares with its volume as packed in the barrel, about as 1.25 to 1.0. Any uncertainty, therefore, as to which of these volumes is intended is manifestly to be avoided. If packed cement is prescribed for measurement, the barrels themselves, provided they are well filled, serve as convenient units, and may be used as measures for the broken stone and sand. If the cement is delivered in bags, as is commonly the case, the contents of each bag is usually an even fraction (one-third or one-fourth) of a barrel. In the interest of definiteness, it is well, however, to specify that a given weight of cement, say 380 pounds, shall be considered to correspond to a given volume of cement, say 3.5 cubic feet. It is, perhaps, just as well to specify that all ingredients shall be measured loose. This method is sometimes more convenient, and accords better with the practice in the laboratories.

The clauses concerning mixing are also frequently lacking in definiteness, although it is well known that the strength of concrete depends very greatly on the thoroughness of the mixing. To specify simply

that the ingredients shall be "thoroughly mixed," or "mixed to the satisfaction of the engineer," is wholly indefinite, and obviously unfair to the contractor. The aim should be to specify as clearly as possible just how the mixing is to be accomplished, especially where the work is to be performed by hand-labor. For large operations, on which mechanical mixers are likely to be employed, it is difficult to draw up the specifications for mixing with the degree of definiteness that is desirable, in view of the diversified types and varieties of such machines.

It should be remembered that, within limits, there is no better way of improving the quality of concrete than by the expenditure of some added time and labor in the mixing. To insure a thorough blending of all ingredients, the cement and sand should first be thoroughly mixed by turning over with shovels; water should then be added and the process continued. The mortar thus prepared should be spread evenly over the stones, which should previously have been thoroughly wetted; and the entire mass should then be thoroughly mixed by means of shovels. The number of turnings at each stage of the process should be definitely stipulated. For the mixing of the dry sand and cement it is probably best to specify that this shall be continued until the mixture is brought to a uniform color.

Concerning the best proportions of water in concrete, it may be said that there is at present a decided tendency toward the use of wetter mixtures. That this is a step in the right direction is hardly to be doubted. It is true that laboratory tests in general indicate a somewhat greater strength for well-rammed, dry mixtures. Evidence is not lacking, however, that wet mixtures develop greater strength ultimately. But, however that may be, the difference is not material. From a practical standpoint the fact remains that unless there be a sufficiently liberal use of water—too much rather than too little—the mass cannot be properly consolidated, no matter how thoroughly it is rammed or how rigid the supervision. The use of wetter mixtures economizes labor and produces a sounder and better product. In the case of concrete-steel there is the added advantage that a wet mixture insures a better bond between the two materials.

As to sand, experiments show clearly that coarse sand is far better than fine sand, and that mixed sizes of grain reduce the proportion of voids materially and give the strongest mortar. The presence of loam and clay in sand is usually considered highly objectionable.

Recent experiments seem to show, however, that the presence of such foreign matter up to at least 15 per cent. actually increases the strength of the mortar and does not impair its weathering qualities perceptibly. If these conclusions should be confirmed by more extended tests, the usual requirements as to the cleanness of the sand might be modified to advantage.

CHARLES M. MILLS.

Concrete in recent years, being more widely used than ever before, enhanced in importance and adaptability for new uses, by its combination with steel, the investigation of its properties is engaging increased attention, with advantage to its successful and judicious use.

With an *ossature* of steel, to use the apt expression of the French, concrete renders available permanent and economical forms of construction, not attainable by either masonry or metal alone. Problems involving earth pressure, and met in the designing of foundations, not to speak of structures above ground, may be attacked with great satisfaction by making direct provision for bending stresses, avoiding uncertainties in many cases as to the behavior of plain concrete or masonry structures, and rendering unnecessary the use of structural steel with its added cost, and in many situations of doubtful permanence.

To place the remarks to follow in order, they will be reduced to six topics, and comprise brief references to a few of the salient points in each, as it would be impossible to cover the whole ground in an entire evening.

In compliance with a request of the chairman of your Information Committee, that some photographs of the Market Street Subway work be shown, I have brought a few slides exhibiting some of the concrete construction.

The first topic is—

*The Quality of Materials.*—The material probably first claiming our attention is the cement. The early strength of Portland cement, enabling concrete to sustain a relatively high stress at early ages, and its greater uniformity and reliability, have resulted in its general use for concrete in high-class work. One of the chief concerns of the engineer, as to the efficiency of his designs in concrete, is the integrity of the composition, making the detection of destructive elements

in cements, tending to disintegration of the mass, of vital importance.

The information elicited in the protracted and still current discussion of the boiling or steam tests, or a combination of both, for the early detection of unsoundness within a permissible period of time, in connection with such personal observations as the speaker has had opportunity to make, has resulted in the adoption of the requirement for three hours immersion in steam followed by five hours in boiling water, the specimens being kept twenty-four hours after gauging. Concrete made from cement which has not stood an accelerated test, undoubtedly stands to-day without showing any unfavorable indications, but it is unsafe to rely too certainly on such evidence, in the absence of particulars as to the interval of time between the testing and the use of the cement. To the speaker, the use of the accelerated test, with a coördinating limitation of anhydrous sulphuric acid, is a safe course, until the current investigations and discussions have elicited more conclusive information. As the test is used to a large extent in the laboratories at the cement mills, for the manufacturers' information, it is doubtful if insistence on the test makes much difference in the price of cement, except probably in times of stringency in the market. Cement which fails to pass the test, frequently will pass it if seasoned for a time and retested. The test undoubtedly facilitates the detection of cement which requires seasoning, and protects the engineer to that extent.

To give the best results and economize in cement, the aggregate should be graded in size, and include the product of the crusher up to the maximum sized stone allowed, and preferably the dust as well. The dust and fine screenings, say up to $\frac{1}{4}$ inch in size, should be kept separate and used in place of an equivalent volume of sand or gravel.

As the strength of cubes of concrete diminishes as the amount of mortar increases, as compared with the stone aggregate, other conditions being equal, the gradation of the sizes of the stone aggregate, to minimize the voids to be filled with mortar, is very desirable. When coarse sand or gravel is used in the mortar, the better it is graded in size, the stronger the mortar. The stereotyped expression found in specifications, that sand or gravel shall be "free from loam," is rarely fulfilled, unless the material is procured from special localities, frequently beyond commercial limits of access, or a high price is paid for unusually well washed or clean material. In view of the presence of what is termed loam, but often consisting of clay and disintegrated

minerals mingled with oxide of iron, in most if not all of the gravels and sands furnished for use in this city for construction purposes, it might be better to fix a limit for the proportion of such materials as would be allowed. Such a limitation would be helpful to inspectors, and obviate the always objectionable feature of an inoperative requirement in the specifications. Perhaps after a proper limit had been determined, a standard turbidity tube for quick determinations by inspectors would be convenient, such test to be confirmed, when necessary, by more exact methods. Loam proper, containing organic matter, recognizable by the color, should be rigidly excluded, and the more nearly sand and gravel consists of clean silicious material, the safer it is for use. Further reference to the effect of the presence of loam in sand and gravel will be made in the following description of a few tests, made in the laboratory of the Philadelphia Rapid Transit Co., the results of which will be shown on a slide.

The tests were made on briquettes of the standard form, to observe the results of mixtures made with Portland cement and gravel from the excavation in Market Street, Jersey gravel, stone grits, and stone dust, and are shown as an illustration of the system of testing in use, to control the selection and use of materials.

A gravel was found in the excavation for the side-wall and sewer, on the south side of Market Street, where the work is now in progress, well graded in size, and superior in this respect to any gravels from other sources offered for use. After screening, it fulfilled the requirements for "coarse sand or gravel, graded from coarse to fine to reject all particles exceeding $\frac{1}{4}$ inch in diameter," as required by the specifications for use with crushed stone in concrete, except in the particular as to its freedom from loam. The Jersey gravels offered for use contained too small a proportion of coarse particles and a large proportion of fine, apparently quite uniform in size, and contained from 10 to 30 per cent. of the fine clayey and decomposed mineral matter associated with oxide of iron referred to above, and which, for brevity, will be termed "loam" in the following.

Some of the tests were made to determine the effect of the loam as found in the excavation gravel, and the effect of using the gravel without washing. The results of some of these tests are given in the following table. The averages for the several groups of briquettes are given, and, in accordance with request, also the individual result from each briquette, as it may be desired to compare the individual results with the averages.

## TESTS OF BRIQUETTES OF GRAVELS AND GRITS WITH VARYING PERCENTAGES OF "LOAM."

| Material. | Percentage Loam. | Temperature. | | Percentage Water. | Tensile Strength—1 Day Air, 6 Days Water. | Tensile Strength—1 Day Air, 27 Days Water. |
|---|---|---|---|---|---|---|
| | | Air. | Water. | | | |
| *A.* Neat Portland Cement (used in these tests). | .. | 65 | 63 | 21.0 | 546 | 846 |
| | .. | .. | .. | .. | 468 | 618 |
| | .. | .. | .. | .. | 564 | 811 |
| | .. | .. | .. | .. | 530 | 761 |
| | .. | .. | .. | .. | .. | 938 |
| | .. | .. | .. | .. | .. | 1199 |
| Average | .. | .. | .. | .. | 527 | 862 |
| *B.* Standard Quartz Sand (used in laboratory)—1 cement to 3 sand. | .. | 65 | 63 | 9.9 | 187 | 280 |
| | .. | .. | .. | .. | 181 | 264 |
| | .. | .. | .. | .. | 165 | 225 |
| | .. | .. | .. | .. | 168 | 285 |
| | .. | .. | .. | .. | .. | 266 |
| | .. | .. | .. | .. | .. | 257 |
| Average | .. | .. | .. | .. | 175 | 263 |
| *C.* Excavation Gravel, unwashed, unscreened—1 cement to 3 gravel. | 25 | 65 | 63 | 11.2 | 133 | 296 |
| | .. | .. | .. | .. | 272 | 327 |
| | .. | .. | .. | .. | 234 | 326 |
| | .. | .. | .. | .. | 194 | 337 |
| | .. | .. | .. | .. | .. | 293 |
| Average | .. | .. | .. | .. | 208 | 316 |
| *D.* Excavation Gravel, washed, unscreened—1 cement to 3 gravel. | 3 | 65 | 63 | 10.7 | 269 | 327 |
| | .. | .. | .. | .. | 207 | 346 |
| | .. | .. | .. | .. | 215 | 375 |
| | .. | .. | .. | .. | 228 | 353 |
| | .. | .. | .. | .. | .. | 375 |
| Average | .. | .. | .. | .. | 230 | 355 |
| *E.* Excavation Gravel, unwashed, screened—1 cement to 3 gravel. | 25.2 | 65 | 63 | 13.7 | 244 | 368 |
| | .. | .. | .. | .. | 219 | 361 |
| | .. | .. | .. | .. | 190 | 355 |
| | .. | .. | .. | .. | 225 | 308 |
| | .. | .. | .. | .. | .. | 328 |
| | .. | .. | .. | .. | .. | 290 |
| Average | .. | .. | .. | .. | 219 | 335 |
| *F.* Excavation Gravel, washed, screened—1 cement to 3 gravel. | 3.2 | 65 | 63 | 11.2 | 225 | 420 |
| | .. | .. | .. | .. | 211 | 350 |
| | .. | .. | .. | .. | 197 | 152* |
| | .. | .. | .. | .. | 210 | 382 |
| | .. | .. | .. | .. | .. | 325 |
| | .. | .. | .. | .. | .. | 356 |
| Average | .. | .. | .. | .. | 211 | 367 |
| *G.* Trap Rock Dust (with 28 per cent. retained on No. 20 sieve)—1 cement, 3 grit. | 16.4 | 65 | 63 | 15.0 | 200 | 373 |
| | .. | .. | .. | .. | 221 | 381 |
| | .. | .. | .. | .. | 220 | 411 |
| | .. | .. | .. | .. | 212 | 390 |
| | .. | .. | .. | .. | .. | 392 |
| | .. | .. | .. | .. | .. | 366 |
| Average | .. | .. | .. | .. | 213 | 385 |

* Not included in average.

TESTS OF BRIQUETTES OF GRAVELS AND GRITS WITH VARYING PERCENTAGES OF "LOAM."—(*Continued.*)

| Material. | Percentage Loam. | Temperature. | | Percentage Water. | Tensile Strength—1 Day Air, 6 Days Water. | Tensile Strength—1 Day Air, 27 Days Water. |
|---|---|---|---|---|---|---|
| | | Air. | Water. | | | |
| *H.* Trap Rock Grit—1 cement, 3 grit. | 11.4 | 65 | 63 | 12.5 | 280 | 475 |
| | .. | .. | .. | .. | 279 | 479 |
| | .. | .. | .. | .. | 289 | 477 |
| | .. | .. | .. | .. | 280 | 435 |
| | .. | .. | .. | .. | .. | 432 |
| | .. | .. | .. | .. | .. | 458 |
| Average | .. | .. | .. | .. | 282 | 459 |
| *J.* Crushed Trap Rock—1 cement, 3 crushed rock. | .. | 65 | 63 | 11.2 | 321 | 447 |
| | .. | .. | .. | .. | 291 | 391 |
| | .. | .. | .. | .. | 225 | 454 |
| | .. | .. | .. | .. | .. | 412 |
| | .. | .. | .. | .. | .. | 400 |
| | .. | .. | .. | .. | .. | 390 |
| Average | .. | .. | .. | .. | 279 | 416 |
| *K.* Trap Rock Grit and Excavation Gravel, unwashed, screened—1 cement, 1½ grit, 1½ gravel. | .. | 65 | 63 | 12.5 | 209 | 375 |
| | .. | .. | .. | .. | 216 | 341 |
| | .. | .. | .. | .. | 236 | 338 |
| | .. | .. | .. | .. | 212 | 422 |
| | .. | .. | .. | .. | .. | 329 |
| | .. | .. | .. | .. | .. | 431 |
| Average | .. | .. | .. | .. | 218 | 372 |
| *L.* Jersey Bank Gravel,*—1 cement, 3 gravel. | 11.6 | 65 | 63 | 13.7 | 128 | 203 |
| | .. | .. | .. | .. | 135 | 210 |
| | .. | .. | .. | .. | 151 | 242 |
| | .. | .. | .. | .. | 149 | 236 |
| | .. | .. | .. | .. | .. | 223 |
| | .. | .. | .. | .. | .. | 244 |
| Average | .. | .. | .. | .. | 141 | 226 |
| *M.* Jersey Bank Gravel,*—1 cement, 3 gravel. | 12.5 | 65 | 63 | 13.7 | 103 | 266 |
| | .. | .. | .. | .. | 104 | 227 |
| | .. | .. | .. | .. | 109 | 277 |
| | .. | .. | .. | .. | 122 | 227 |
| | .. | .. | .. | .. | .. | 251 |
| Average | .. | .. | .. | .. | 109 | 249 |

In mixing the batches comprising each group of briquettes, the consistency was made as uniform as possible to minimize variations liable from varying proportions of water. Neat tests of the Portland cement used for all of the briquettes is given in group A. All briquettes were made by the same operator, and tested by one operator.

* Gravel in groups L and M—from different sources.

You will notice that group B gives the results with standard quartz sand, passing and retained on 20 and 30 sieves respectively, and that they are lower than all other groups except L and M, the last two of the series. It is commonly found that the standard sand gives results inferior to those from bank sand or gravel, even though the latter contains more or less loam. This is undoubtedly due to the greater coarseness and gradation of size in the particles in the sand or gravel.

As explaining the low results for groups L and M, it may be stated that these gravels were too uniformly fine; L passing about 40 per cent., and M 51 per cent., on No. 50 sieves, with a very small proportion of large particles. Group L contained 11.6 per cent., and group M, 12.5 per cent. of loam. If perfectly clean, it is probable that the results would have exceeded those for the standard sand. It has been found that the loam in the excavation gravel contains about 50 per cent. of finely comminuted silica.

It will be noticed that the tests for the excavated gravel, groups C and F inclusive, give average results from 316 to 367 pounds per square inch for twenty-eight days, and that the averages show that the effect of washing for the range of the briquettes shown in the table, was attended with an increase of about 10 per cent. in strength. This increase in group F is derived by eliminating the low test of 152 pounds, manifestly defective.

The greater strength, when the particles are coarse and graded in size, is well shown by comparing groups C to F, with groups L and M. Although group E contains 25.2 per cent. of loam, double that in group M, the average tensile strength is about 35 per cent. in excess for the former. As stated above, the excavated gravels in groups C to F were all very well graded from coarse to fine, while those in groups L and M were fine, with a large proportion quite uniform in size, with too few large particles. Group K comprises briquettes made of the excavation gravel screened but unwashed, and trap rock grit in equal proportions. The favorable effect of the addition of the grit will be observed.

The high results of the tests with the crushed rock, grit, and stone dust, agree with similar results as frequently reported. The loam given in the crushed rock and the grit, is fine mineral matter, differing in color from that found in the gravels.

As the character of the excavation gravel gave such good results, and so much difficulty was experienced in procuring material which

gave equal, to say nothing of better results, it is being used in various parts of the work after screening, mixed with an equal part of crushed trap rock grit. Tests are being made as the work progresses, so that a constant check is being maintained as a guide. It is the intention to institute a system of crushing tests on 6-inch cubes.

*Proportioning of the Materials.*—The proportioning of the cement to the aggregate should correspond with the duty required, with necessary allowance for difficulties liable to confusion in measuring, where varying proportions are used in different parts of a piece of work. The quantity of cement to be used should be considered in connection with the aggregate commercially procurable. Where water-tightness is necessary, it seems desirable to fill the voids as completely as practicable; at the same time it is to be remembered that leakage may be more serious from fissures, liable to be developed by shrinkage or cracking, if an excess of rich mortar is used, so that a leaner mixture, which may perhaps involve a more or less cellular structure, may be safer, unless for very high pressures, and then the introduction of steel fabric is advantageous.

Rather than take up a formal discussion of the theory of proportions, with which no doubt those of you who are interested in concrete are already familiar, and particularly as the time is limited, I will speak of the proportioning of concrete for use in the Subway.

For the side-walls, floors and roof, the specifications provide that the proportions for the side-walls shall be $1 : 2\frac{1}{2} : 5$, to allow the use of 500 pounds per square inch as a working stress, and as it was desired to reduce percolation to a minimum, the mortar was fixed at 1 to $2\frac{1}{2}$, aimed to fill the voids due to the probable use of more or less gravel deficient in gradation of the particles. A slight excess of mortar was desired to allow for the probable use of indifferently graded crushed stone, as I have had difficulty in getting crushed stone well graded in size. Proportions of $1 : 2 : 4$ have frequently been used abroad and in this country for similar duty. The proportion of cement as placed at $1 : 2\frac{1}{2} : 5$ was not deemed so rich as to invite liability of cracks due to shrinkage. To guard against the latter, secondary rods were introduced, so that the embedded steel would result in a distribution of minute detailed fractures instead of fewer injurious large fractures, should fractures occur. An important office of the secondary rods is also to prevent cracking of the concrete due to expansion and contraction from changes of temperature, as no expansion joints are made in the side-walls. The moisture and the

relatively equable temperature of the earth, very favorable for concrete, were also considered in the selection of the proportions.

Investigations are in progress to guide in the future proportioning of cement to the aggregate, so that judicious modifications may be made. At this time, as stated above, in various parts of the work, the 2½ parts of gravel are replaced by trap rock grit and screened gravel from the excavation, in equal proportions. In general mass work, and in ordinary situations, the proportions are 1 : 3 : 6. The unit of measurement of cement is 100 pounds, or approximately 1 cubic foot packed. Gravel, grit, and stone are measured as shoveled into the mixing boxes, without shaking or packing.

*Mixing and Consistency.*—It is difficult to secure thorough mixing without mechanical action. Except in cases where concrete is made in small quantities, a good mechanical mixer should be used. Thorough incorporation is best secured by positive mechanical action, independent of gravity, although more power is required than for mixers utilizing the tumbling principle, such as the Cubical, the Ransome, the McKelvey and other types. The latter, however, gives very good results. The trituration secured by mechanical mixing promotes the thorough coating with cement of the particles of the sand, gravel, or stone dust, and reduces the danger of lack of contact of the cement with the stone and gravel, due to the adhesion of wet stone dust, and loam, which cannot be as well accomplished by hand mixing.

As thorough tamping is difficult to secure, even with constant supervision, particularly in reinforced concrete, the speaker long ago decided that the best way is to make the mixture wet. By wet, I mean so that it quakes like jelly. The lubrication of the particles permits them to glide and interlock, and agitation by the amount of tamping attainable, assists the expulsion of any excess of water to the surface, which excess, as far as the speaker's observation has reached, has done no harm. The structure of wet concrete, from specimens examined, is more dense, and contrasts markedly with that where relatively dry mixtures have been used, filling the space about embedded steel, and producing better surfaces against forms. If the necessary tamping could be secured, the difference in the resulting structure would be reduced, but I do not believe that any amount of tamping, even in relatively thin layers, will give the dense structure secured by a wet mixture, moderately tamped.

The early strength of well-tamped medium mixtures is greater than that of wet mixtures. The elaborate tests made by Mr. Rafter indicate

that the strength of medium wet mixtures is greater than for very wet mixtures, as tested for periods from 570 to 670 days. Other experiments show that after the lapse of from three to six months, the strength of the wet mixtures approximates that of the medium mixtures, and in some cases surpasses it. It is to be remembered that laboratory tests, even though conducted so as to be as much as possible like actual work, are by no means conclusive when all the conditions of actual work are considered. From my experience, I think the discount due to a possible excess of water is more than compensated for by the difficulties in securing tamping, and the neglect in watering and keeping wet the drier mixtures, without which they suffer, as is generally recognized.

*Placing in the Work.*—Forms need to be reasonably water-tight, to prevent effluent of the wet mortar. Where fair material for forms is procured, not too thin, the material can be used three or four times, and perhaps in some cases more than four. The timber for face forms on the Subway wall-work is two-inch dressed, grooved and tongued, and can be turned, on repeated use, if found desirable. Hasty caulking with oakum is done on back forms where not as fine a grade of lumber may be used, or where the labor of placing it is reduced.

*Surface Treatment.*—The speaker has sought satisfactory methods of surface treatment, to obviate the naked appearance of even well-faced work. The futility of the addition of extraneous material, applied after forms are removed, has long been recognized, and brushing with a thin grout of fine sand and cement is the most general treatment. I understand that the speaker to follow has been experimenting to secure a rough finish, and I hope that we may hear from him as to the results. I have seen a pebble finish applied to the surface of concrete, which in some cases had endured several years' exposure; in other cases slabs of mortar comprising the matrix sustaining the pebbles had sloughed off. A pebble surface, applied at the face forms, as the body of the concrete is placed, would be durable, and could be utilized in connection with moulding, to effect coursing where desired. Unevenness of color, and cracks due to settlement or other causes, are masked by a rough surface treatment, and compensate for the lack of the opportunity for remedial pointing, as in the case of the joints in stonework, which unfortunately is often found convenient.

*Reinforced Concrete and the Subway Work.*—In the beginning of the speaker's work in reinforced concrete, more reliance was placed

on the adhesion of the concrete to the steel reinforcement than he now thinks is justified. It was found that the intensity of the stress tending to rupture the adhesion where the maximum increment of tension is imposed on the bars by the concrete, became too large a proportion of the value of the adhesion, as shown by the most recent tests, and formed rods were adopted, the formed rods making a mechanical lock to the concrete. The adhesion is more or less affected by the disturbance produced by the deposition and tamping of the concrete, rods placed horizontally being less liable to this disturbance than when placed vertically. In placing vertical rods within the side-wall forms, they are shaken more or less, even when carefully held by templets and intermediate wooden braces or other supports, so that the formation of the bond between the steel and the metal is interrupted. Another factor to diminish the adhesion between the steel and the concrete, is that in narrow vertical forms a wet mixture facilitates filling them and securing close contact with all parts of the reinforcement, as it is difficult to tamp thoroughly. The slight contraction or settlement, noticeable when the wet mixture is used, produces a slight downward movement of the concrete about the bars, liable to interfere to some extent with the formation of the bond between the steel and the mortar. In many cases tamping with a drier mixture is facilitated by adding sections of the forms on one face as the concreting progresses, a method usual in building columns or pillars.

In order that you may better understand the views to be shown, a slide will now be exhibited, which has been prepared from the tracing showing the cross-section of the Subway on Market Street. You will see that the side-walls are of reinforced concrete, and that the roof consists of 20-inch steel beams with concrete jack-arches, the beams being spaced five feet apart. It may be noted here that the original design for the roof included the use of reinforced concrete. The methods of construction contemplated at the time were subsequently modified, a more detailed or partial method being desired, which was facilitated by the use of the beams. Running longitudinally, and just inside of the principal rods of the side-walls, are the smaller distributing rods for webbing, and to increase the resistance to cracking due to probable shrinkage, and temperature changes. Placed over the tops of the roof beams, and parallel to them, are sheets of wire mesh, with the principal or heavier wires transverse to the beams, to reduce liability of cracking in the concrete over the top flanges, by which leakage might enter and work along the webs.

The 4-foot 9-inch sewer along the south side-wall, and a part of the sewers along the north wall, are of reinforced concrete. The sewer along the south wall is being built along with the side-wall, the trench being opened to sufficient width to permit the construction of both. The use of reinforced concrete for these sewers was adopted to render them less liable to fracture, by which leaks would be created alongside of the Subway walls, as more or less disturbance is liable as the excavation for the Subway proceeds.

A drain is placed under each of the two outside tracks, with laterals every fifty feet, extending to the exterior of the base of the side-walls. The main drains lead to sumps served by pumps. These drains serve temporarily to facilitate keeping the excavation dry during construction. From knowledge secured during the excavation for the sewers, before the Subway proper was begun, it was assumed as improbable that any large quantity of water would have to be permanently handled if the drains were built. By this arrangement there is no attempt to exclude water, by which a head would be placed on the side-walls, and the entire structure should be drier. The depth of this part of the Subway, and the attendant conditions, are favorable to this treatment, often not permissible. Waterproofing is placed on the roof and side-walls.

HENRY H. QUIMBY.

*Mr. President and Gentlemen:* The masonry part of some of the bridges that have been built recently by the city of Philadelphia, and some under construction now, is concrete, either straight or in combination with steel. At the request of the Information Committee, and by permission of Chief Webster, I have here, to present on the screen, the plans of some of these structures, that may contain features of interest. No. 1 is a view of the northeast abutment of the Seventeenth Street bridge across the Reading Railroad, at the intersection of Indiana Avenue, beyond the old Sixteenth Street station. The bridge is a 132-foot through-truss span. The masonry is all concrete, 1–3–6, with granite pedestal blocks under the truss shoes. Because of the skew the length of this abutment is nearly 140 feet, with the wings in almost a direct line, in which we have provided no expansion joints, or rather contraction joints, as perhaps they are better called. The only provision against transverse cracks consists of five steel rods, $1\frac{1}{4}$ inches square, imbedded below the level of the bridge seat and continued to the ends of the wings. The abutment

was built in hot weather and has been exposed to the weather on both sides until now, and is probably thoroughly chilled by this time, and no cracks have developed anywhere. The work is founded on dry gravel six feet below the rails.

No. 2. This is a photographic view of the south abutment of the same bridge, built the same as the north abutment. It shows the scoring of the face into courses and blocks similar to ashlar masonry. This is not for the purpose of imitating stone, but it conceals defects of joints between layers, and prevents the eye from seeing the effect of warps in the planks of the face forms, and gives a pleasanter appearance to the work besides. The scoring is accomplished by tacking half round beads to the planks of the forms, and their imprint is left.

No. 3. Plan of one of the piers of Passyunk Avenue Bridge across the Schuylkill at Point Breeze. Only one abutment and four of the piers of that bridge are under contract as yet, Councils not having made appropriation for more than that portion of the bridge. The foundations are piles which are driven to rock. The plumb or bearing piles are from 50 to 60 feet long. The spur or batter piles from 60 to 70 feet long. The mud is so soft that the piles entered it a distance of twenty to thirty feet, below the bottom of the ten-foot deep excavation, by their own weight and that of the four and a half-ton hammer on them, before a blow was struck. The top ends of the piles are surrounded by a bed of concrete four feet deep. As the bearing power of the mud is so uncertain, the principal office of this bed of concrete is to firmly fix the top ends of the piles, stiffening them against buckling under their load. In order to prevent any possible splitting of this concrete along the lines of the outer piles, it has been reinforced with $\frac{7}{8}$-inch steel rods, forming loops around the outer piles and extending back 6 feet into the block. They are imbedded about six inches above the bottom of the layer. The two longitudinal timbers, against which the batter piles chock, are 12 inches by 12 inches, as are also the caps of the piles. Three longitudinal 2-inch rods are imbedded in the base of the neat work, and three similar rods along the top, to prevent any possible cracking transversely. There is a wire net, or expanded metal to be imbedded in the coping layer to prevent longitudinal cracks, and the capping of the piles is expected to prevent longitudinal cracking at the bottom. The bearing blocks or pedestals for the bridge trusses are granite.

No. 4. Plan of the west abutment of the same bridge. Foundations

similar to the pier just shown, only necessarily larger in area. The passive character of the bottom made necessary a platform under the back filling, also supported on piles, and the forward thrust of the mud under the approach embankment is taken care of with about ninety spur piles. The possibility of an embankment being built on the mud along one side of the bridge, induced the use of transverse spur piles at each end of the abutment and piers. The face of the abutment has a batter of 1 in 8, and, in addition, the toe is extended to distribute the load evenly over all the foundation piles. The overturning effect of the earth fill back of the abutment, together with the vertical pressure from the three steel trusses of 100-foot span, and the weight of the concrete body, is uniformly distributed over the plumb piles, giving to each a load of 13 tons. The projection of the toe is an inverted cantilever in which the tension is taken by 1-inch square steel rods spaced twelve inches apart, and the projection at the ends is taken care of in the same way; so that there is a mattress of 1-inch square rods throughout the base of the abutment. This cantilever construction is an interesting feature of the design and is practicable only in concrete masonry.

No. 5. Plan of Stokley Street Bridge abutments, just west of the Chestnut Hill branch of the Pennsylvania Railroad, carrying Stokley Street across the Richmond Branch of the Reading Railroad. The bridge is a 56-foot clear span, sixty feet wide, and the abutments, with the wings, are 120 feet long. There are no expansion joints in them. Rods are provided for imbedding in the top of the back wall of each abutment. Both abutments are at this time finished up to the bridge seats and, as the back walls have been left to be built after the steel work is riveted, the rods are not yet in the work. In all this cold weather the abutments, which were built in warm weather, have been exposed on both sides, but there are no cracks anywhere in them. Indications are that expansion joints are not needed in that length of wall. There is a 6-foot sewer passing underneath the abutments.

No. 6. Plan of concrete-steel arch on the line of Frankford Avenue, over Poquessing Creek one mile above Torresdale. Span 71 feet in the clear; rise $9\frac{1}{2}$ feet; curve segmental, with line of thrust always within middle third of ring; bridge sixty feet wide; sixteen latticed steel ribs, each made of $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$ inch angles laced with $2 \times \frac{1}{4}$ inch bars. The ribs are tied together transversely with angle struts. The parapet is of concrete with steel rods imbedded. There will

be no steel exposed anywhere on the bridge and probably nothing about it, except the paving, will require attention for maintenance in our time. The arch ring is 16 inches thick at the crown, and 3 feet 4 inches at the springing line, giving everywhere 3 inches of concrete over the steel. The compression at the crown, due to the total load, is such that if the load be wholly carried by the concrete the unit stress will be 240 pounds per square inch. If it should be all carried by the steel, the steel would be strained to thirty thousand pounds per square inch. The division of the stress between the two materials will depend less upon their relative areas and moduli of elasticity than upon the method employed in erection. The effects of the shrinkage of the concrete in the shortening of the imbedded steel and resulting initial compression in it, will depend largely upon the method of procedure in placing the concrete. If the steel ribs be supported on the centering, as is usual if not universal, and the concrete placed around them, working from the abutments toward the crown, the steel will be in very considerable tension at the crown before keying, and therefore its action in service after keying, doubtful. If, on the other hand, the steel ribs are in compression to start with and, in their capacity of an arch, support both their own weight and that of the arch ring as it grows, they will be certain to take a fair share of the total load. I therefore suggest both the practicability and the desirability of utilizing the steel ribs for carrying the centering, and thereby dispensing with falsework. This of course can be done only when the steel is in large units, as in the bridge just shown, and is not possible where the steel is in small units, as in the Edwin Thacher design.

The sketch on the screen illustrates the proposed order of procedure. Suspend, with easily detachable hangers from the steel ribs, the lines of joists needed to carry the lagging. Erect forms on the lagging, to divide the arch into transverse sections, at distances apart to be determined by the amount of concrete that can be placed daily, the complete sections resembling voussoirs. With the proper order of succession in placing the sections, being careful to always deposit the concrete in corresponding sections on opposite sides simultaneously, the eccentricity of the line of thrust of the growing load will be so slight that the steel arch will not be appreciably deformed, and, as by the hardening of the successive sections the reinforcement of the steel will proceed with the increase of the weight to be carried, the maximum stress in the steel will be reached only when the rein-

forcement is almost complete. After the concrete ring is closed, there can be no deforming influence except the filling, which will merely make up the permanent and symmetrical load. By this method we will get a finished arch that will have absolutely no deformation after it is keyed. The only deformation during the construction will be from the compression of the steel, which will shorten and cause a slight flattening of the curve of the arch. In the case of the Poquessing Creek bridge, shown a moment ago, the total pressure per square inch on the steel, due to the weight of lagging and concrete, would be something over thirteen thousand pounds, and this will cause the steel ribs to shorten just about as much as the concrete around them will contract in shrinking—an ideal condition. If a concrete arch be built on falsework centering, when the supports are withdrawn there will very likely be some deformation of it. Some arches rise at the crown and others deflect; the action depends probably, in part, on the composition of the concrete and the proportions at different parts of the ring; but most largely on the way in which the concrete is put in. At any rate, no man seems to be able to determine in advance what the action will be. If the shape of the arch is changed after it is keyed and set, certainly initial stresses are set up—unbalanced, perhaps excessive: what they are we can never determine, and we do not know how destructive they may eventually be in concrete.

I have another suggestion to make, which is in connection with the design of reinforced concrete arches, and which, I think, fairly comes under Professor Marburg's subheading of applications. Perhaps the better way to build a composite arch is not to put the steel in a longitudinal direction, as in the design just shown, or as in the Thacher plan, but to put all the steel in a direction normal to the line of strain—radial to the curve of the arch, corresponding to the position of the joints of the voussoirs of a stone arch, thus using steel only to bind the concrete together, which will both increase its crushing strength and prevent its ever splitting into fragments. Expanded metal or woven wire, of section to be determined by experiment and judgment rather than calculation, thus imbedded in the mass of concrete, will act as "hooping" to resist the bursting effect of pressure, and if there should ever develop a tendency to separation of the steel and cement, any breaking of the bond of union, or any swelling of the steel from rust, the transverse reinforcement will never operate to split up the arch ring, whereas longitudinal reinforcement would, under such conditions, become a disintegrating factor. Of course such an arch

must be designed as a stone arch would be—of shape to avoid tension at any point.

In order to test this theory of construction I had two lots of concrete cubes made ten days ago, some plain and some reinforced, and crushed them to-day. In one lot the reinforcement was expanded metal in a horizontal plane at the middle of the cubes, and in the other lot the metal was light woven wire placed vertically. Of the first lot the armored cubes were about 30 per cent. stronger than the plain, and of the other lot, where the steel was in the direction of the pressure and too light to have any resistance to compression, the plain cubes were a little higher in crushing resistance than the armored. The cubes were only ten days old, but the expanded metal in one of the first lot was ruptured, indicating that the metal was light for the duty, and a much higher percentage of gain in strength will be obtained with heavier reinforcement. These tests are not claimed to be at all conclusive, but they seemed to me to confirm the theory that steel imbedded in an arch in a radial direction, at distances apart equal to, say, half the thickness of the ring at any point, would give the most value in strength and durability. The theory does not depend wholly upon the increased value of the armored cube—upon its increased resistance to crushing, but also upon its preservative effect on the concrete. The expanded metal in these cubes was about one-twelfth inch in thickness and expanded into meshes one-inch size. The idea did not occur to me long enough ago to enable me to get cubes older than ten days for tests.

There are two things in connection with the working of concrete that I want to speak of. One is a more efficient form of rammer than any of those now in use, and the other is the surface finish to which Mr. Mills referred. If the concrete to be used is of such consistency that it requires ramming to compact it, then the instrument should be one that will have penetration as well as weight. I noticed that Professor Marburg, in referring to that operation, called it "tamping." I think that he did not use the word "ramming" at all. I think it should be rammed if it be stiff—not tamped, but rammed. An ordinary pickax will do fairly good work, but not very much of it. A railroad trackman's tool for tamping the ballast under ties is much better, because it is blunt. An ordinary spade would do good work, but we cannot expect the men to put enough weight on it. The logical outcome of such reasoning is a rammer like this [exhibiting rammer]. It is merely the iron moulder's rammer en-

larged. It has penetration. The operator has merely to raise it, and its weight—30 pounds—will do the rest. It might be better if a little heavier, and would probably stand forty pounds. The paver's rammer is fifty pounds in weight, and therefore this ought not to be a burden to the man to work. This instrument has been in use at different points. It is the only one in existence so far as I know. It does satisfactory work from the engineer's standpoint. How the contractor regards it I do not know, but I think that the contractor ought to be satisfied with it if he is required by one means or another to get his concrete compact and filled. Possibly the most "all 'round" satisfactory work will be done by mixing the concrete to such consistency that it does not require any more ramming than the tramping of the laborer in it and the poking with his shovel. Men who have been used to stiff concrete are somewhat startled to see the "soup" that nowadays is poured into moulds, and it seems to be a revelation to them to find that, after the forms are taken off of that concrete, it rings to the hammer.

In regard to the finish of face work—my method is simply to wash it with water, but do it when the concrete is green—to take the forms off before the concrete is hardened—after it has set up and has sufficient strength to maintain itself and the load of a few layers above it perhaps, but not after it has hardened. In summer weather, I find that the ordinary concrete is just about right to wash and finish in twenty-four hours after it is laid. I noticed some recently that had been in the forms for over a week, during the cold weather, and when the forms were taken off, it was a little too green to finish smooth, but just right to wash up rough. This method is cheaper than any other I know of, and it is very much handsomer and I believe very much more durable. I have some specimens of different mixtures here. This is a mixture of cement, gravel and trap rock screenings. That may be rubbed fairly smooth if permitted to get hard and rubbed with a brick. Water must be used freely. If the work be green enough, all you have to do is to squirt water on it with a good nozzle pressure. The whole process consists of removing the cement from over and around the gravel and grit, getting rid of the rich cement surface, which is subject to hair cracks, and exposing the clean stone or sand of the face. This is a facing of limestone gravel and sand. This has not been sufficiently washed. You can see that the cement has not all been taken off. This is a sand finish. Here are different proportions of trap rock screenings and cement. The only sand in

Copy of Letter

PHILADELPHIA. July 21st, 1909.

In your reply please refer to File No. 928

Subject: Cement in cubic yard of concrete

Mr. Samuel Tobias Wagner,

Ass't Engineer, Philadelphia & Reading Railway Co.

Dear Sir:

Replying to your letter of the 20th inst., in reference to how many barrels of cement per cubic yard are used in 1 : 3 : 6 concrete, - I give the following information:-

"Taylor and Thompson's book - page 230 - upon the assumption that a barrel holds 3.5 cu. ft. and that voids in the aggregate are 40%, it requires 1.13 barrels of cement to make one cubic yard of concrete, 1 : 3 : 6 mix."

In connection with the construction of concrete well built in place on top of blocks or on platform in the construction of the Delaware avenue bulkhead, considerable data were collected upon this subject; also the investigation covered experiments with wet and dry concrete, the question not having been finally determined at that time. We determined that the contents of a barrel of Portland cement equals 3-2/3 cu. ft. and the sand and stone were proportioned on this standard. The mix used was 1 : 3 : 6 - therefore, the quantities were as follows:- cement, one barrel = 3-2/3 cu. ft., sand, three barrels = 11 cu. ft., and stone, six barrels = 22 cu. ft. In one section the wall contained 30.8 cu. yds. When built with dry concrete it required 34 batches to fill the form, making each batch contain 24.4 cu. ft. of concrete. The same sized section when built with wet concrete held 37 batches making each batch contain 22.5 cu. ft. of concrete. In other words, when the concrete was mixed very wet three more batches were needed to construct

2.

a section of wall than when dry concrete was used. The wet mix resulted in a more compact wall. In other cases where the wall was built on temporary platform a section contained 38 cu. yds. with dry concrete equalling 44 batches, making each batch contain 23.3 cu. ft. of concrete. With wet concrete a section of the same size required 45½ batches making each batch contain 22.54 cu. ft. of concrete. In regard to the construction of concrete blocks which were built in tight steel forms containing on an average 16½ cu. yds. the number of batches required varied from 17½ to 19 depending on the degree of moisture. The greater number contained 18½ batches. When 17½ batches were used each batch contained 25.5 cu. ft. When 18½ batches were used each batch contained 24.1 cu. ft. of concrete. The stone aggregate used was well graded; the sand used - jersey gravel - also well graded as to size. From measurements taken I have concluded that it requires about 1-1/8 barrels of cement to make a cubic yard of concrete 1 : 3 : 6 mix, with a well graded aggregate.

Yours very truly,

(GSW-HL) Chief Engineer and Surveyor.

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them is fine particles of the crushed stone. Here is a still rougher surface. It is a matter of taste which you prefer. The probability is that the rough surface is the most durable that you can get with plastic materials.

## COMMUNICATED DISCUSSIONS.

### GEORGE S. WEBSTER.

In concrete construction it has been found that a greater quantity of ingredients may be incorporated in a given section when the concrete is made with a large percentage of water than when made with a small percentage. It is also found that a wet mixture gives a smoother surface and results in a more compact wall.

On the Delaware Avenue improvement the contents of a barrel of Portland cement were determined to be $3\frac{2}{3}$ cubic feet, and all sand and stone scales were made accordingly. The concrete was made 1–3–6—cement, $3\frac{2}{3}$ cubic feet; sand, 11 cubic feet; stone, 22 cubic feet. If the voids were just filled, then one barrel of cement would make 22 cubic feet of concrete. The broken stone was graded in size and the sand used was New Jersey bank sand. This also was graded in size.

The construction of a section of the bulkhead wall at Chestnut Street, on timber platform, containing 38.0 cubic yards when built dry and rammed by ordinary labor, without any special care, required 44 batches; each batch therefore contained 23.3 cubic feet. A similar section of wall, when built very wet, held $45\frac{1}{2}$ batches, each containing therefore 22.54 cubic feet. Similar experiments were made, and in all cases it was found that a wall built of wet concrete was the more compact, and contained a larger quantity of ingredients.

### CHARLES H. UMSTEAD.

The subject is a very broad one, and a single phase of it could hardly be covered in one discussion. Concrete enters into nearly every structure which the engineer designs to-day, and it would be well for the Club to divide the subject into three or four parts, discussing each part separately, so as to avoid repetition.

It would be very fortunate for us all, were a committee appointed similar to the one about to be appointed by the American Society of Civil Engineers on "Concrete and Steel-Concrete," to investigate the proper mixtures and their best application from an economical standpoint.

Our positive knowledge concerning this material is very meager, considering the number of engineers concerned in its use. It is true that we have tabulated a lot of results, but they are neither correlated, nor do they agree. Each corporation sets up its own little laboratory, and declares that its methods are correct and that it must follow that its neighbors are wrong. What we need is a unification of concrete tests; a "clearing-house" to which all conflicting results can be referred. Until this is done, our progress in defining the properties of the new material must be extremely slow and erratic.

The Germans and French have data and records concerning this material which we have never dreamed of, and which must remain a closed book to all except those who are fortunate enough to know how to read technical records in these languages. Their engineers have long ago given up methods of application of concrete, which we are holding to tenaciously, simply because our concrete laboratories have not revealed our mistakes.

About ten years ago many of the concrete specifications called for a physical test of Portland cement, the requirements ranging from 200 to 400 pounds per square inch in tension, with the exception of those issued by the Department of Public Works in the city of Philadelphia, which has always demanded about 50 to 100 pounds above the general requirements in practice. This was due to the facilities afforded for rapid testing in their cement laboratory, it being the pioneer laboratory, so far as tests over long periods are concerned. Of late years many other laboratories have been equipped, modeled in a measure after this one, and the result is that now the designing engineer can reasonably expect and has specified American Portland cement having a tensile strength of 650 pounds per square inch, and I am told that in a recent contract in New York, involving many thousand cubic yards of concrete, a tensile strength of 750 pounds in twenty-eight days was guaranteed under bond.

In supervising the breaking of a large number of test-pieces, representing more than twenty brands of American Portland cement, during the past few years, the writer has noticed that it was the usual occurrance for the machine to register above 750 pounds in tension per square inch, and very rarely below 650 pounds in a twenty-eight-day test. Referring again to the older specifications for concrete, requiring only 300 to 400 pounds in twenty-eight days for the cement in tension, we also find that the usual mixture required was 1–2–4 and 1–3–6. The latter mixture being used only in very large masses. To-day we

specify 600 to 700 pounds per square inch in twenty-eight days for neat Portland cement and often find records of 900 to 1000 pounds in our cement laboratories, *i. e.*, 300 pounds above requirements. In the specifications of to-day, the former mixtures, 1–2–4 and 1–3–6, are maintained. We can only conclude, that either we designed our concrete structures ten years ago with too low a factor of safety, or to-day we are wasting the money of our clients, by expending it where it is *not* necessary. On the other hand, if a 1–2–4 mixture was on the side of safety ten years ago, it follows by analogy that concretes made from a 1–4–7 mixture with the improved and finely-ground Portland cements of to-day, are equally safe and durable. In older countries, even a leaner mixture is regularly specified for important works, with good results. The cement manufacturer need have no fear of the possible curtailment of his product, should the designing engineers specify this change. "Dollar cement" will become as popular as "dollar gas," its cheapness leading to an enormous demand for it.

The other ingredients, rock, sand and gravel, not being considered so much as objects of manufacture, do not receive the close attention which they require. In an important concrete construction, sustaining heavy concentrated loads, the crushed stone and sand should become as much the subjects of critical tests as does the cement. There is doubtful economy in using a cement bought and tested to stand 600 to 700 pounds per square inch with crushed stone which is friable, or with sand and gravel which contain silt and clay in measurable quantities.

The crushed stone delivered to an important job should be tested frequently by some of the short laboratory tests, for absorptive qualities, for abrasion, and for specific gravity. Stone with a specific gravity of at least $2\frac{6}{10}$ should be demanded, if the locality will yield it; and if not, anything less than $2\frac{3}{10}$ should be rejected. The sand should be tested for silt, for voids, and for fineness; the silt and foreign matter being expressed as a percentage of the original dry weight of the sand as delivered. When 10 per cent. by weight passes a number 30 sieve, this fact should be a cause for rejection, depending upon the importance of the work.

The results of tests for the effects of various sizes of sand grains upon the strength of mortar and concrete will be found recorded in the "Journal of the Franklin Institute" by Mr. Wheeler and Mr. Cooper of the U. S. Army Engineers, also by M. Ferët, of Boulogne, France, in the "Annals des Ponts et Chaussées."

The water is an important ingredient, both in its chemical and physical action upon the concrete. The failure of the majestic concrete and granite docks at Aberdeen shook the confidence of European engineers in this material for a long time. Upon examination by some of the most noted engineers and chemists in Europe, it was decided that the failure was caused by the chemical action of the sea-water on the concrete, aided at some points by the frost. Recently the practice of mixing sea-water with concrete has revived in this country with doubtful predictions as to the result. This has occurred mostly in harbor works where fresh water or rain-water is accessible only in very small quantities. Our chemists do not predict with any certainty what action will take place upon our concrete structures founded in sea-water. We do know that existing structures present a very rough and unfinished exterior after being subjected to the action of the sea for a year or two. Whether or not this is due to the salt in the water alone, or to the combined action of the salt and the force of the waves, our chemists should be prevailed upon to assume the province of determining. The real cause of the apparent breakdown of our concrete piers and breakwaters founded in sea-water, as influenced both by freezing, and the action of salt, should be known.

Professor Michaelis of Berlin has started such tests from a laboratory standpoint, and a committee is expected to report upon the subject in St. Petersburg some time in 1904.

The deposition of concrete into large open caissons, was tested by General Newton, U. S. Army, in New York Harbor. He found that at the end of each day's work, a coating of light material, with no cementing properties, covered the top of the concrete. The concrete deposited on the following day would not adhere to that which was deposited on the day previous. When this caisson was hoisted from the bottom of the harbor with its enclosed block of concrete, it was found upon removal of the wooden molds, that there were as many distinct blocks of concrete as there had been days upon which the operation took place.

This method of building harbor works had long since been abandoned by every harbor engineer in Europe, and the only reason known why General Newton should have made this test, is that he wished to determine whether or not the American Portland cements contained the same deleterious substances found in the imported German cement of that day.

The practice seems to be, to deposit concrete for harbor work either

in closed caissons, or in open caissons which have been made water-tight and pumped perfectly dry.

In building concrete works far out to sea, the use of salt water will greatly economize the first cost of construction, but whether the lasting qualities of the work will have been jeopardized by its use, remains to be determined, and in a few cases which have come to the writer's notice, we will not have to wait very long.

A few engineers have specified that no dynamite should be used in quarrying out the rock in sizes suitable for the crushers, believing that the stone would be unfit for important works. In the same specification you will find a clause permitting the stone to be heated to an abnormally high temperature to drive out the frost in severe climates. This heating of the stones is of doubtful benefit to the concrete, unless the temperature of the heating apparatus is within the control of the operator.

The method of heating stone for concrete most commonly used in the Eastern States, is to build a wood fire inside a large section of a discarded steel tank or smokestack, laid horizontally on the ground, and a ton or two of crushed stone is heaped over the heated cylinder. The result is evident. The stones in contact with the cylinder are overheated and consequently weakened long before the stones on top of the heap have been warmed sufficiently to drive out the frost. A furnace so designed that heated air of a known temperature can be blown over and through the pile of crushed stone is necessary for safe concrete construction in times of frost or extremely low temperatures.

*Application.*—On heavy concrete works, where vertical faces will be exposed to view, and it is desirable to have very few if any marks showing between the succeeding layers, the writer proceeds as follows: At the end of a day's work, or of a horizontal section, the surface is rammed hard and troweled to a hard, glassy finish, the same as found on our best concrete sidewalks, care being taken to have this horizontal surface perfectly level where the joint is to occur, and for a space of three or four inches from the edge. Next morning, this surface is washed thoroughly, and when nearly dry, neat cement is deposited uniformly over the surface through a number 50 sieve to a depth of $\frac{1}{32}$ of an inch. The concrete for the succeeding layer is then firmly rammed until the moisture is barely sufficient to take up the thin coating of neat cement. If care is used, the joint will be horizontal, and will not be visible except upon very close examination.

The layers of concrete at the rear of the four-inch strips are always made as rough as possible before setting takes place.

Efficient ramming of concrete will increase its strength from 10 to 50 per cent. over that which has been only dumped into position.

It is often specified for heavy concrete walls for harbors that the exposed vertical faces shall be followed up with one inch of concrete with all large stones eliminated, or with a strong cement mortar, and to be carried up at the same time with the concrete backing. A number of expensive harbor works have been made unsightly by the careless application of the outer wearing surface. You can never apply it after the structure has been built. It may stick for one season, but the action of frost and sea-water will soon cause it to lose all adhesion. One way to overcome the difficulty, which the writer has applied successfully, is to first make the wooden forms of thick, tongued and grooved lumber, smooth inside and covered with an application of yellow soap and alum-water or refrigerator paper of an oily nature, which will not absorb water or wrinkle.

As the concrete is being deposited near the paper-covered planks, a V-shaped block of wood or truncated wedge is inserted between the forms and the concrete, so as to keep the concrete away from the paper. The concrete, which should be very dry at this location, is then rammed extremely hard, so that when the wedge is withdrawn, the concrete will have enough rigidity to permit the forcing of stiff mortar into the space left by the wedge. After sufficient tamping of the mortar to fill any voids between the mortar and the forms, the wedge is reset, and the operation repeated with the next horizontal layer of concrete. This operation cannot be carried out with a so-called "wet concrete," for the reason that the backing must always be at least four inches ahead of the facing, and unless some measure can be taken to dispose of the surface water, due to ramming, the water will find its way to the facing, doing untold mischief, if not damaging the whole work. It is evident that the forms should be very strong and well braced to withstand the most ordinary wave action, as any vibrations, however slight, will show their effects when the forms have been removed. The smallest leak in the forms should be stopped at once, for any surging or lowering of the tide will cause the water to run out, washing the sand and cement in its path: the consequence is, that when the forms are removed, the stones having no binder around them, will drop out, leaving cavities in the face of the structure.

Too much care cannot be spent in the oversight of concrete works

under construction. After the concrete specification has been carefully drawn up by the chief engineer, a copy is handed over to his inspector (who is usually a new graduate) to see that its provisions are carried out. Men of this class do not take kindly to watching men dump stuff into one end of a mixing machine and hauling it away from the other end to be dumped again. Having just passed his "exam" on "Euler's criterion" and the "Chezy formula," he looks upon such an assignment as a little beneath his capabilities, and will sometimes ask to be given charge of a survey or some cleaner job. The fact of the matter is, that at no stage of the work will he be called upon to exercise more care and judgment than when placing the concrete for a foundation, no matter whether the structure be a pier for a bridge, a covering for a filtration plant, or a retaining wall for a harbor. If the builder, who may be inclined to be "slippery," does not succeed in beating him on the concrete foundations, he can rest assured that he will have comparatively little chance for complaint on the remainder of the structure. At this point, more than at any other, will an ill-considered decision involve the reputation of his chief and himself in disaster.

# REINFORCED CONCRETE IN BUILDING CONSTRUCTION.

EMILE G. PERROT.

*Read February 20, 1904.*

*Mr. President and Gentlemen:* It is my purpose, in re-opening the discussion on this topic, to bring to your attention the application of this material to building construction, particularly to factory or mill building, and to discuss the subject from the architect's standpoint, showing the advantages and drawbacks incident to its use.

With the marked improvement in the design of mills, brought about largely by the requirements of the insurance companies with a view to reducing the loss from fire, the modern mill, erected on the principle of "slow-burning mill construction," and equipped with all the accessories to prevent the spread of fire, should one take place, has come to be regarded as a standard for such buildings; the idea of constructing fireproof mills not having taken a very firm root in this country. Since the advent here, however, of reinforced concrete as a means of construction, the subject has engaged the attention of architects and engineers, until to-day, we see its use becoming more general; but, like all new systems, it has met with varied success.

Being closely identified with the construction of mill buildings, the problem of making them more nearly fireproof and less susceptible to deterioration and at the same time consistent with a fair first cost, has, we think, been solved in the use of this system of construction. Moreover, the scarcity of good quality, large size, yellow pine timber for posts and girders in slow-burning mill construction, has often compelled the use of a greater number of posts or other feature of construction not altogether desirable.

In considering the advantages and disadvantages of reinforced concrete, the architect is confronted with many important questions which must be answered aright before any definite plans can be drawn.

First and most important, Is reinforced concrete "reliable"—will it stand up?

Second: Does its added weight work to its disadvantage?

Third: Can it be erected with sufficient speed and in weather of varying degrees of temperature?

Fourth: Does the stony and monolithic character of the construction render the building less adaptable for the introduction of overhead shafting, fixtures, etc.?

Fifth: Is it fireproof?

These questions naturally occur to one who has little or no experience with this construction, and it is only the proper solution of them that will result in the more general adoption of reinforced concrete. The answer to the first question depends on certain factors, the most important of which embodies the personal element; or, in other words, reinforced concrete in the hands of thorough and conscientious workers will be just as safe as any other form of construction, while the reverse is true if the designing and execution is left to inexperienced persons. The question of its added weight can be passed by as one of little moment, when we consider the saving of cost, effected by its use, over other fireproof methods of construction.

Can reinforced concrete be erected with sufficient speed and in weather of varying degrees of temperature? The first part of this question I will answer by giving the record of the reconstruction of the Forrest Laundry last year. This building is a four-story and basement structure 50 feet wide by 160 feet long. The entire structure was finished on December 12, 1903, whereas the contract did not require its completion until January 15, 1904. On November 26th all the plastering was finished; the concrete construction of the entire building, except the roof on top of the tank tower, was completed on October 29th. As the work was given out on July 25th, this shows a very rapid progress. Since the work of erecting the staging for the concrete construction started on August 5th, the time occupied for putting in the concrete construction was, therefore, twelve weeks. As this involved the laying of about 35,000 square feet of floor and roof, this is remarkably rapid progress. As to laying reinforced concrete in freezing weather, I might say that it is not impracticable to do so, provided the temperature does not fall below about 26 degrees Fah., but the precaution of leaving the forms or centering in position until the concrete has thoroughly set and hardened, after the thawing process, is absolutely necessary.

The stony and monolithic character of reinforced concrete is somewhat of an objection for buildings in which the location of the machinery is not predetermined, unless some means are adopted by which the shifting hangers, etc., can be located at any point. This

feature of the construction I will take up more fully in the latter part of this paper.

The fireproof quality of reinforced concrete has been established beyond a doubt, not only by actual conflagrations, but also by experimental fire tests made under the direction of the Philadelphia Bureau of Building Inspection and the New York Building Bureau.

The following are extracts from the report of Building Inspector Paul J. Essick, Jr., on the fire test at Philadelpha:

PHILADELPHIA, *June* 20, 1903.

ROBERT C. HILL, ESQ., *Chief of Bureau of Building Inspection.*

*Dear Sir:* Pursuant to your direction, I visited the foundry of Messrs. Cresswell & Waters Co., Nicetown, in the yard of which a test was to be made of the de Valliere system of reinforced concrete floor, beams and columns by Mr. J. O. Ellinger, the manager, and beg leave to report on said test as follows: A section of the floor had been erected enclosed on four sides with 13-inch brick walls to a height level with the top of the concrete floor having a fire-door, front and back draft opening, and grate surface with four chimneys so as to make a regular furnace.

The construction of the section was as follows:

*Floor:* Size 8 feet by 18 feet, equals 144 square feet of floor surface.

*Columns:* 4 by 16-inch columns flush with ends but 10 inches from side, reinforced with four steel rods $1\frac{1}{8}$ inches diameter, placed perpendicular at 10-inch centers. Height of column: 9 feet $1\frac{3}{4}$ inches.

*Girders:* Two girders 8 inches by 14 inches reinforced by four steel rods 1 inch diameter hung in stirrups of twisted $\frac{5}{16}$-inch steel, and having an eye at top through which the $\frac{5}{16}$-inch round rods of the slab were placed. These four rods were placed within 2 inches of the bottom of girder, the two lower rods running straight to the column, while the upper two rods were bent so as to reach the top of girder at the column.

*Floor:* The floor was 5 inches thick, having a layer of $\frac{5}{16}$-inch rods at bottom of floor, 8-inch centers, and another layer running from bottom at center to top at outer edge, for purpose of strengthening the overhang of 14 inches of the floor.

The columns, beams, and floor having been built continuously, it was in one solid mass.

The proportions of the concrete were: 1 of Alpha Portland cement, 3 of Jersey gravel, and 5 of trap rock. Age: two months. Slight fire started on 16th inst. to dry out brickwork.

A load of 150 pounds per square foot was placed on slab June 16, 1903; total load 21,600 pounds of pig iron.

*Start of Test:* Fire test, started at 9.10 A. M., June 17, 1903, using oak cord wood for fuel. At 1.15 hose was turned on from fire-plug, using the regulation hose of the Fire Department and with a pressure at fire hydrant of 65 pounds. The total deflection, under load of 150 pounds per square foot, and fire and water, was $2\frac{5}{12}$ inches.

On examination at 9.10 A. M., June 18, 1903, I found the concrete columns, beams, and slab, with considerable heat, at least 150 degrees, continuing warm all day and cooling exceedingly slowly. No separation whatever had taken place between slab and beams. No spalling of exposed surfaces was observed, though bottom surface of slab was at a cherry red. The mean average readings of pyrometers during the fire was 1776 degrees.

Correcting the levels, I find that there was a total deflection, at this time, of 1 inch, showing that the floor recovered in cooling $1\frac{5}{12}$ inches. Inside, the surface of concrete shows a slight superficial crack near front end. The northeast column shows a shearing break about $3\frac{6}{10}$ inch, vertically across corner. Other parts in splendid condition.

On increasing load of pig-iron the northwest column showed a perpendicular crack through center. Part of the back wall of furnace was torn down to see the back of columns, and a crack was found running nearly around both north columns.

On June 19th, at 9.15 A. M., fifteen hours after the last reading, there was no increase in the deflection under a load of 602 pounds per square foot. The back columns, or those on the north, showed a buckle of $\frac{3}{8}$ of an inch.

One other important feature, which is interesting to the architect and engineer, inasmuch as it affects the pecuniary interest of the client, is the rate of insurance. Making the comparison with similar buildings of the slow-burning type, everything else being equal, the rate on the reinforced concrete type is considerably lower than on the slow-burning type; this is seen in the case of the Bilgram Machine Shop, where the rate is only twenty cents per hundred, while on the slow-burning type the rate would be more than double this amount. The rate on the Forrest Laundry is thirty-five cents per hundred, while on a laundry building of the slow-burning type the rate would be seventy cents per hundred. We understand from the insurance agent that the rate on this particular building is cheaper than any other laundry rate in the United States; furthermore, the same owner, while in temporary quarters after the destruction of his building by fire (the building being of slow-burning mill construction, sprinkled), paid $1.57 per hundred insurance. This gives some idea of the saving effected by using this system of construction.

The cost of reinforced concrete, as compared with the slow-burning type on the one hand and steel frame, fireproofed with terra cotta, on the other, reveals some interesting figures: The following data are from the actual estimates received on the buildings mentioned. The bids of the Forrest Laundry for the slow-burning type amounted to

$1.07 per square foot of floor area; for the reinforced concrete, $1.45 per square foot; for steel floor and roof construction fireproofed, the cost would have been $1.85 per square foot. The bids on the Union Mission Hospital do not show the same variation; the construction being lighter, the cost was not affected as much as with a heavy construction. The actual bids on this building were $2.45 per square foot for reinforced concrete and $2.54 per square foot for steel construction, fireproofed, making a total difference between the two systems of almost $2500 in favor of the concrete. We see at once, therefore, that

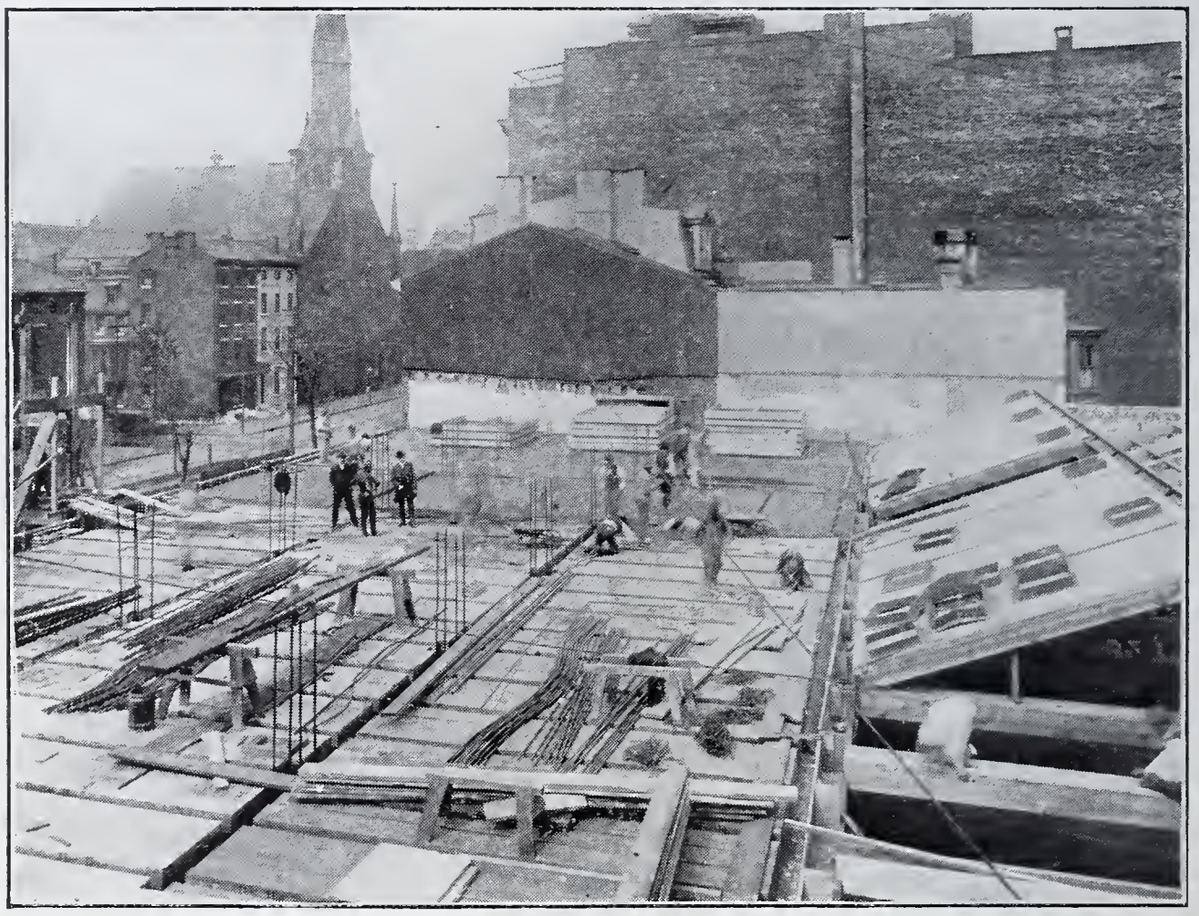


Fig. 1.—View of Second Floor, Bilgram Machine Shop, during Construction.

while as a fireproof construction, reinforced concrete is cheaper than fireproof steel construction, it is at the same time not too expensive to prevent its use in factory or mill construction.

The first building designed by us, in which reinforced concrete forms the integral part, and which, I think, is the first building ever erected in this country, having a saw-tooth roof, constructed of reinforced concrete, is the Hugo Bilgram Machine Shop; the building being the second one in Philadelphia in which reinforced concrete has been used for the entire floor and roof construction.

I might mention here, that it is due to the indefatigable labors of Mr. J. O. Ellinger, whose work in this field is well known, that reinforced concrete is a reality in Philadelphia, and through his persistent efforts, in conducting to a successful issue his fire tests, the Philadelphia Bureau of Building Inspection has placed buildings constructed of reinforced concrete under the head of buildings of the

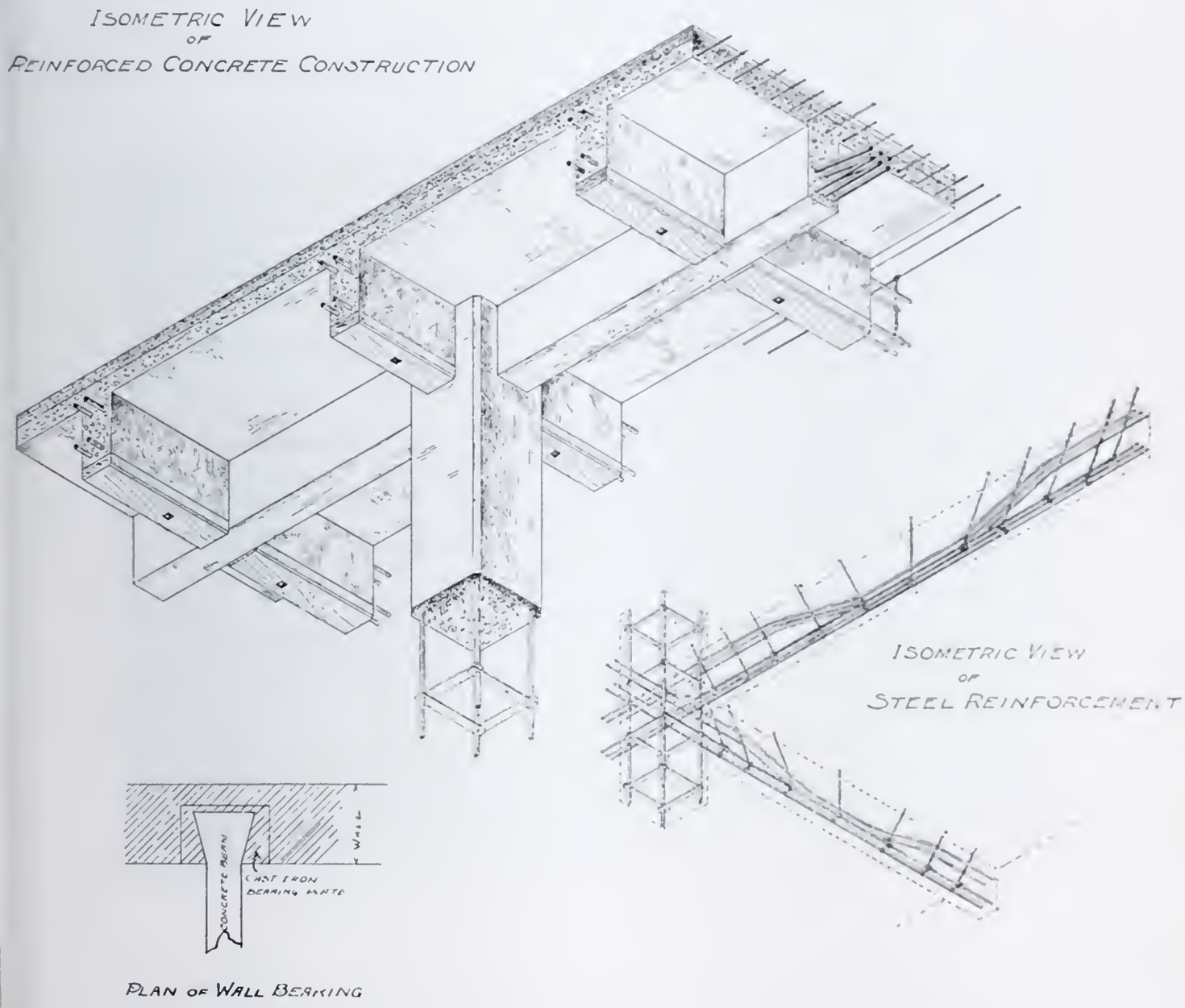



FIG. 2.

first class; likewise, New York has placed his system in the class which comes under the head of "fireproof."

To come to the practical application of the various patented systems, such as the Ransome, De Valliere, Hennebique, etc., we find that a disposition of posts and girders similar to that in slow-burning mill construction is entirely satisfactory, and that it is only necessary to

consider the wood construction as being petrified and we have the construction in reinforced concrete; that is, the heavy beams taking the place of the cross girder and the concrete slab the 3 or 4 inch plank. As to making the walls of concrete in mill buildings built in the city, there is no saving of cost, and our practice so far has been to use brick walls. An isometric view of such a floor is shown in Fig. 2. It has, in addition to the cross beam, a longitudinal beam or girder. The construction is what would be termed a framed construction if it were executed in wood. The longitudinal girder is a few inches deeper than the cross girder for a very important reason;

Fig. 3.—Basement of Hugo Bilgram's Machine Shop.

that is, to permit the bottom rods in the beams to rest on top of the bottom rods of the longitudinal girder, so as to obtain direct bearing, one on the other, and thus avoid straining the concrete. Other details of construction are shown in this view, such as the stringer pieces to secure the shafting. An isometric view of the steel reinforcement is shown in the lower right-hand corner. In the lower left-hand corner is shown the method of anchoring concrete beams to the wall; a dove-tail pocket being built by the mason, into which the concrete is poured. Cast or wrought iron bearing plates should be placed under all girders.

It has been our practice, in the better grade of buildings, to plaster with white-coat the reinforced concrete, which increases the brilliancy of the building at least twenty-five per cent. Where a very smooth finish is not absolutely necessary, the concrete work can be painted with some make of cold-water paint or white-washed. This was done in the the basement of the Hugo Bilgram Machine Shop with very good results.

*Theory.*—The usual theory of the resistance of materials, based on

Fig. 4.—Interior Second Story, Bilgram's Machine Shop, showing Concrete Plastered, and Wood Stringer Pieces for Hangers.

the hypothesis that a section plane before bending remains sensibly plane after bending, while not held by all engineers as being absolutely exact, is, however, sufficiently so for all practical considerations when applied to simple flexure; and this hypothesis forms the basis of all the formulæ used in the writer's calculations. Such French engineers as Considere and Christophe, and American engineers, as Thatcher, hold to the above tenets, and I do not see any good reason why the theory of reinforced concrete beams should be so refined as to reduce the calculations to an exactness which is un-

doubtedly rendered *nil* by the inequalities almost sure to exist in the concrete mixture and irregular workmanship.

On the assumption that, within the elastic limit, the stresses are uniformly varying across the section, the fundamental formula for the flexure of beams may be reduced to the following, for reinforced concrete beams of rectangular section, with reinforcement in the bottom only, neglecting the effect of the concrete in tension:

$$M = \frac{2}{3} a \times \frac{1}{2} p a e + t s b.$$

in which:

M = bending moment in inch pounds:
a = the distance from the neutral axis to the most remote fibre in compression:
p = the unit compressive strain on the concrete:
e = the width of the beam:
t = the unit tensile strain on the steel:
s = the area of the steel:
b = the distance from the neutral axis to the center of action of the steel.

The determination of the neutral axis is, therefore, the key to the solution of the equation. If we represent the height of the beam by h, then the fraction $\frac{a}{h}$, which we shall call x in the next formula, represents the fractional part of the height of the beam in compression; likewise, the fraction $\frac{s}{e\,h}$, which we shall call y, equals the percentage of the metal in relation to the total sectional area of the beam. By assuming the coefficient of elasticity of steel as being twenty times that of concrete (the value established by the Philadelphia Bureau of Building Inspection), we deduce the following formula, which defines the position of the neutral axis in fractions of the percentage, or—

$$x = 20y\left(-1 + \sqrt{1 + \frac{1}{12}y}\right).$$

This formula is based upon the steel reinforcement being located five-sixths the depth of the beams from the top.

In calculating the strength of beams with floor slab united thereto, the beams and slabs are considered a T section and the beam figured accordingly; of course, should the neutral axis fall in the slab, the formula used for rectangular beams will hold good for these T sections, since we neglect the consideration of the concrete in tension and are only concerned with that in compression.

The formula for T sections, then, when the neutral axis falls below the slab, becomes—

$$M = \frac{p}{6a}\left[a^2w\,(3h' - a) - (a - g)^2\,(w - e)\,(3h' - a - 2g)\right].$$

in which p, a, and e have the same meaning as before, and w = the width of the slab.

h′ = the distance from the top of the slab to the center of action of the reinforcement.

g = the thickness of slab.

Fig. 5.—View of Second Floor of Forrest Laundry during Construction.

The working stresses of the concrete we have assumed as 500 pounds per square inch, and that of the steel as 16,000 pounds per square inch; these values being established by the Philadelphia Bureau of Building Inspection.

The effect of shear upon a beam seems to have been very little considered in the early study of reinforced concrete, but since data obtained by practical tests seem to indicate that beams designed without the use of steel, to take up the shearing strains, fail by the cracking of the concrete, several systems have been devised to meet

this objection. The De Valliere has a very good form of twisted stirrup, which is built in the beam and unites the steel rods of the beams to the reinforcement of the slab. The Kahn system employs a square bar with side wings bent up at an incline. The stirrup in this case being originally part of the bar and cut away, leaving just enough material to unite the two securely together. The Hennebique system uses stirrups bent in the form of a U-shaped loop extending under the tension rods and running up through the beam and projecting into the slab. The oldest system in the country, the

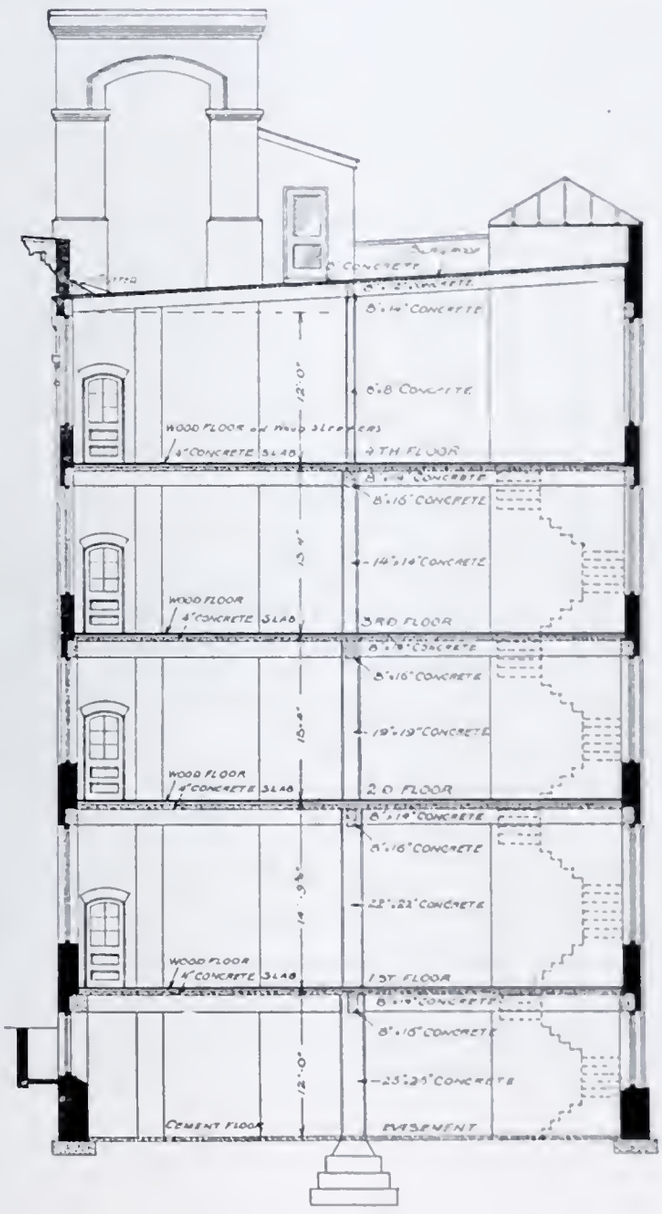
Fig. 6.—Floor Load Test, Second Story, Forrest Laundry.

Ransome, is usually constructed without stirrups, but personally I think it is not only more logical but safer to use stirrups of some form.

The dangers of reinforced concrete I mentioned earlier in the evening, and to show how a legitimate system of construction can be abused, I refer you a list of failures of concrete buildings for the year 1903, given in the January (1904) number of the magazine "Fireproof." The list comprises fifteen failures for the year.

One important investigation in the matter of the protection of the embedded steel in concrete was made by our firm. A test prism, 6 by

6 by 8 inches long with four $\frac{5}{16}$-inch rods, was placed in brine for six months in order to determine the effect of this solution on the embedded steel, having in mind the design of a certain building in which brine or salt water was used very freely. We made this test to determine the advisability of this form of construction. When the cube was broken open, the rods showed no trace of rust and were as bright




CROSS SECTION.

Fig. 7.—Forrest Laundry.

as the day they were embedded in the concrete. This is only another demonstration of the protection afforded the reinforcement by the concrete, and is especially interesting, as all the rods were placed within an inch of one face of the prism and the ends of some were

as close as $\frac{3}{8}$ of an inch to the end of the prism. These ends were as bright as when the rods were inserted.

We had another series of tests, made by Riehle Bros., to obtain the values for the adhesion of plain steel rods to the concrete, which is as follows:

Laboratory No. of Test $\begin{matrix}19998\\20001\end{matrix}$

PHILADELPHIA, *Feb.* 20, 1904.

BALLINGER & PERROT, *Philadelphia, Pa.*

We have this day tested for you four tests of rods embedded in concrete for adhesion, and beg to submit the following report:

FIG. 8.—BUILDINGS OF JEANESVILLE IRON WORKS CO. DURING CONSTRUCTION, SHOWING REINFORCED CONCRETE TOWER.

*Note.*—Tests made to ascertain adhesion between steel rods and 1, 3, 5 mixture of concrete seven months old.

$\frac{1}{4}$-inch, $\frac{5}{16}$-inch, and $\frac{9}{16}$-inch rods, embedded in one prism and rusted before insertion.

$\frac{3}{4}$-inch rod, embedded in a second concrete prism and entirely free from rust before insertion in prism.

Each prism 12 inches long, giving a 12-inch length of contact to all rods.

| Diam. and Circum. of rods in inches. | | Area of Rod in Contact (square inch). | Total Pressure in Pounds: Release. | Friction. | Pressure in pounds per square inch: Release. | Friction. |
|---|---|---|---|---|---|---|
| $\frac{1}{4}$ | .785 | 9.425 | 2670 | 2000 | 283 | 212 |
| $\frac{5}{16}$ | .982 | 11.78 | 2560 | 1200 | 217 | 102 |
| $\frac{9}{16}$ | 1.77 | 21.2 | 2960 | 1350 | 140 | 64 |
| $\frac{3}{4}$ | 2.356 | 28.27 | 5660 | 3200 | 200 | 113 |

The average pressure per square inch for release was, therefore, 210 pounds, and the average friction per square inch was 122¾ pounds. The result of these tests shows that rusted iron rods adhere as firmly as perfectly clean rods. Although the number of tests was not large, we are led to believe that, even though these values appear rather low, they give sufficient information upon which to base our calculations.

## DISCUSSION.

Charles M. Mills.—I would be pleased to learn from Mr. Perrot whether, in the construction of reinforced concrete, he has had an opportunity to observe the effect of a dry and artificially heated atmosphere in the interior of buildings; upon the tendency of concrete to shrink or crack, and if he has noticed such tendency, whether he has preference for any particular proportions of the concrete materials which he thinks would best resist it. I would also be very glad to have him describe a little more fully the expansion joint placed on the sides of the buildings, as exhibited on the screen.

Mr. Perrot.—Answering the first question; the buildings which we have designed have not been erected long enough to determine the action of dry artificial atmosphere on the concrete. On similar buildings, erected in Europe and in other countries, and from data on the subject, we have no fear as to the results or behavior of these buildings. The fire tests show the behavior under different conditions of temperature. I would say that, with my partner, I visited Baltimore last Monday with the view of observing the fire-resisting qualities of concrete, and I was very glad to see that there was one building in the conflagration at Baltimore which stood up, being the only one in the block. All the others fell down. That happened to have a reinforced concrete interior, supported entirely on independent wall columns of concrete. I estimate that the distance between party walls was about 20 feet, and the depth of the building about 80 feet. It was a four-story structure, built with arched floor slabs, about three inches at the crown. The concrete was intact. Some of the party walls had fallen down because they were not properly built, and part of the front had fallen out. This was an old building with the interior reconstructed of concrete. Here is an example of an actual fire test; the concrete being exposed to a high degree of heat. Part of the side wall of the fourth story had fallen down and left the construction exposed, and I understand from the contractors that the concrete in is perfect condition. Samples of concrete which have gone through a fire test show a pinkish tinge. After it comes from the fire it appears to be more or less vitrified. There was another concrete building

which fell down, but from what cause I do not know. If there had been higher buildings alongside of this four-story structure and they had collapsed, nothing could have saved it, because it was of light construction.

In reply to other questions Mr. Perrot made the following statements:

The arched slab is a characteristic form of the Hennebique system. I understand this form of slab was used in connection with the flat slab in the J. L. Mott Iron Works Company's building at Trenton, which failed last December (sketching on the board).

We are building a mill at Bristol in which we are going to have a concrete floor. The distance between girders is 8 feet and we have a five-inch slab. Now, we intend to carry only 150 pounds per square foot. The concrete floor of the Mott building was designed for 250 pounds per square foot, and I do not believe the slab is anything near that thickness. It is altogether a matter of safety. It does not make much difference what system of construction is used; they will all lead to failure if lacking in strength. It is all a matter of design and workmanship.

The vertical rods in the columns take up the bending, which causes compression on one side and tension on the other. In Philadelphia, the Bureau of Building Inspection does not allow the use of a unit strain of more than five hundred pounds per square inch in compression. The rods, therefore, do not count for much except to keep the concrete from cracking. I do not believe in building concrete walls without rods, because they are bound to crack.

It is our custom is to leave floor forms in place two weeks. In constructing the Forrest Laundry we had two sets of forms. The first set was used in the basement to support the first floor, and was left in two weeks. After the concrete was laid on the first floor they built up the forms to support the second floor and by the time the concrete for the second floor was in place, that of the first was sufficiently hardened to use the forms for the third floor, with the necessary alterations, so we took the forms out, and so made good time.

Armored concrete construction may be executed as fast as the material can be put in place. A good many contractors use only one-inch material for the forms. Better contractors use two-inch. Another thing about the forms: they should be put together in such a manner that they can be taken down easily. This is facilitated by not driving the nails as far as the head. There is a waste of material, of course, in transferring forms from one story to another. The loss is about five to ten per cent.

Attempts to color exterior concrete walls by mixing the coloring matter in the concrete have been unsuccessful. The cement acts as a chemical on the color. I would not advocate it. It is better to paint the concrete afterwards. I do not see any good reason for painting it. If you want to get a color scheme, try to use sand which has some kind of color, red or yellow.

Walter F. Ballinger.—There are just two points I wish to mention. Mr. Perrot's remark might have been misunderstood as to a wooden building of our design having fallen down. A portion of a wooden saw-tooth roof construction fell down while in the contractor's hands, before any attempt was made to complete it, due to insufficient shoring. Answering the question that one gentleman asked about the cost compared with other construction, I might

add to the examples which Mr. Perrot has mentioned, that a certain cottage building in connection with this orphanage, which he showed on the screen, which cost about $15,000 in the ordinary construction, would have cost $2,100 more had the floors been of reinforced concrete, with wire lath and cement plaster partitions. You see there is a difference in that case of about fifteen per cent. In the case of the Methodist Hospital Dispensary, for which the contract is just let, the cost in joist construction was $18,000, and the alternate bids showed $3,600 additional for reinforced concrete construction. That would be about twenty per cent. greater for the concrete construction. In a certain factory we had an estimate of $56,000, for slow-burning mill construction, which would have cost $6,000 additional, or $62,000, for concrete, which is an advance, in that case, of about eleven per cent. over slow-burning mill construction. In another building it was found that the omission of the tank with its supports, necessary for a sprinkler system, and the sprinkler system itself, just evened up the cost of a building of concrete reinforcement and one of slow-burning mill construction. That is, it was found that a lower insurance rate would be obtained on a building of reinforced concrete without sprinklers than on a slow-burning mill construction with sprinklers—about one-half the rate —and the cost appeared to be about equal.

Mr. Souder.—There is one point that is interesting to me. I understood Mr. Perrot to say that the concrete is plastered. Was this plastering applied while the concrete was still green or damp, shortly after the forms were moved, or after it became hard? In my experience, plastering concrete work after it has become hard does not give satisfactory results. The plaster does not adhere.

In the case of some of the early concrete bridges built by the city of Philadelphia, a plaster surface was laid on after the concrete had hardened. I have inspected all of these structures and found in many cases that the plaster coating was hollow and in some cases had fallen off. Plastering was also tried on a small house which I built of concrete, but the result was not good.

We used liquid cement. Possibly the surfaces we applied it to were too dry. It was never satisfactory to me. My practice is to apply the cement plaster against the forms, just before the concrete is laid, the whole being compacted by ramming. In this way the plaster is well bonded with the concrete mass. This method was specified for some concrete bridges which I designed for the city of Philadelphia and which gave good results.

Mr. Perrot.—On the interior of a building, we put on the plaster the same as you plaster a brick wall, and that is the way we treated the concrete. Plaster the concrete at the same time you plaster the wall. The plasterers were very particular to use a special mixture which consisted of plaster of paris mixed with a large proportion of lime—really what you would call a white coat. The cement will not discolor the white coat, when painted, if the wall is dry. We have had paint disfigured on a brick wall which was plastered. If the wall is not dry, it makes no difference whether it is cement or what it is, it is going to discolor the paint. That is simply a matter of experience with every kind of construction. With this construction we have used only a white coat, and so far it has been very good. Under vibrating loads the plastering remains in position. Whether it will remain in position ten years from now is a question.

Henry H. Quimby.—When you use the floor slab as part of a beam, how much of the slab in width do you figure on for compression?

Mr. Perrot.—That is the important point. We have compiled a number of tables and formulæ to determine that very thing. We have a system of tables which shows at a glance how far we must place the beams apart in order to have sufficient width of slab. The formula I gave on the board will tell you that. We solve the equation for that particular quantity, namely W, or the width of the slab. Each case has to be worked out, and we have made tables so that they would not have to be worked out a second time.

H. Wilmerding.—I hardly know what to say, except that I have been very much interested in the discussion. Unfortunately I got here too late to hear all of Mr. Perrot's paper. I have just come from Baltimore, where I saw the building which Mr. Perrot described. I understood just before I left Baltimore that the upper floors of that building had softened to such an extent that they probably would have to come down. I would like to ask Mr. Perrot what, in his opinion, would be the cause of that? There was probably no water thrown. Would it be from the heat disintegrating the concrete?

Mr. Perrot.—I think it would. Moreover, I might mention this: we all know that limestone, when it is calcined and water is placed upon it, will expand, as we see every day in making ordinary mortar. If we use limestone in concrete it is simply worthless as a firperoof material. There happened to be a small piece of limestone in the slab on the test house at Nicetown, and during the test that piece swelled and broke out of the slab. It did not do any harm to the floor. The behavior was just the same as that of a piece of limestone in a brick. When the brick is laid up in the wall and absorbs water from the mortar, the calcined limestone will expand and crack the brick. If you use limestone for reinforced concrete it is not fireproof. It would disintegrate under heat and water. If there was anything in the sand or stone in this building of that nature, it would tend to cause disintegration.

J. O. Ellinger.—I have attended a great many meetings at which the subject of reinforced concrete was under discussion, and I think the impression usually left on the minds of the hearers was very much like that of the judge who said, when he addressed the jury, "Gentlemen: If you feel like me you won't believe what either side has said." So much in the way of successful reinforced concrete work has now been done that to attempt to consider this subject as in any way at all mysterious, is vitally wrong. The whole theory of reinforced concrete is just as susceptible of careful analysis and of correct deduction as is the theory of steel or any other construction with which we are familiar.

The attempt on the part of the companies who do concrete work, to make the outside world believe that they alone possess the secrets of this art, is wrong. The calculations, after all, reduce themselves to very simple formulas, with which the engineer in his ordinary everyday work is familiar. It seems to me the following is a good example illustrating this.

Some time ago, last summer, Mr. Mills, whom I believe is somewhere in this room now, sent for me and told me that he worked out his sections for the Philadelphia Subway, using two formulæ, which if I am not mistaken were those of Johnson and Thatcher. In addition to this, he also employed an approximate

one. After Mr. Mills gave me the conditions of load and span, he requested me to work out the amount of steel and concrete which would be required, and entirely independent of Mr. Mills, I did work out the sections, using the method of Ritter of Zurich, and I think that the determinations, based upon these various formulæ, came out within one or two per cent. Such being the case, I do not see that there is anything mysterious about the subject, and I see no reason why any intelligent engineer cannot work out the required sections. On the other hand, I do feel that the best care is necessary in the execution of the work, which should be entrusted only to workmen who are familiar therewith, through experience.

Mr. Perrot in his subject has spoken of the failures which have taken place within the last year in reinforced concrete constructions. Being engaged in this business, I have been and am, of course, vitally interested in the matter and have tried to analyze these failures. In carefully studying the subject, I have found that the general cause of trouble was due to taking down the forms before the concrete was set.

The failure that took place at Binghampton in a concrete construction was due to the lack of inspection on the part of the architects, who permitted reinforced concrete walls to be built, without any reinforcement.

So far as the Trenton failure was concerned, if my understanding be correct, this was due to faulty design, faulty material, and faulty execution. The lesson to be learned from these failures is very simple, and, as I see from my own work, expert help must be had to carry on reinforced concrete constructions. The engineer may design excellently, but if he has not got good aids in the shape of good material and expert workmen to execute his work, I fear he will have poor results. If, on the other hand, his designs be good and the execution entrusted to good men, the results obtained in reinforced concrete construction will be as good as those obtained by any other method. So far as the empiricism of reinforced concrete construction is concerned, as I said at the beginning, I do not think it is more general than the empiricism of steel construction, and the results which are obtained justify this conclusion.

Answering the question as to how much of the floor slab it is usual to take in compression as forming the top part of the beam, I want to say, that the New York Building Department permits the designer to take, for this purpose, a slab five times the width on either side of the beam.

Mr. Quimby.—In regard to the slab width used as part of the beam—it depends in a measure upon the shearing value of the concrete, and any formula for determining the available width must be based upon an assumed shearing value, and include the area for horizontal shear which is the increment whose accumulation produces the flange stress, and must not be lost sight of. Mr. Ellinger stated in effect that calculations of designs of composite construction are as scientific as those used in steel construction. I feel like quarreling with that statement, because of the uncertain strength of concrete. I think that the claim is a little enthusiastic. The most liberal specifications for steel—those issued by the manufacturers themselves—allow a range of only ten thousand pounds, where the mean ultimate is say sixty thousand—a variation of about eight per cent. Concrete cubes put up for test—not the concrete as put into the work, but the cubes put up for the purpose of testing—vary from 500 pounds

to 4000 pounds per square inch in crushing strength. Surely what is put together in the field by workmen, often with no special interest in their work, is likely to have in places even less value.

Mr. Ellinger.—Mr. President: that characterizes what I said, may be, but I have never heard such an extravagant statement in my life as the statement made by the gentleman. In concrete for testing pusposes, unless the cement was so bad that a tyro would have rejected it, no one would ever estimate the value of compression as low as five hundred pounds. Whether the gentleman has seen some extraordinary work which I have not seen, I do not know. Really upon the best authority, I know that in the best accepted tests concrete certainly varies between 2500 and 4000 pounds. In addition—well, I ought not to say any more. It is too late.

Mr. Quimby.—In the city testing laboratory with three months' old cubes of 1, 3, and 6, we have had results below five hundred pounds, and at least one tested up to about 4000 pounds, and it happens that these extremes occurred where the same brand of cement was used. I think there are some gentlemen here who will confirm my statement.

Mr. Ellinger.—I would like to ask Mr. Quimby what cement tested 500 pounds and the age of it.

Mr. Quimby.—The cubes were from thirty to ninety days old, and it happens that the same brand of cement was used in the 4000 pound cube as in those that broke below 500 pounds—the same brand and I think the same mixture.

Mr. Ellinger.—Mr. President, I would like to ask Mr. Quimby whether he, as a scientific man, before he made the test, determined the value of the cement before the cubes were made. That is very important. Mr. Quimby knows that in cements of the same kind, made by the best makers of cement, certain carloads would come up to the highest standard and others be rejected. I would like to know whether the 500 cube was the highest grade or a low grade. Did Mr. Quimby test the cement?

W. Purves Taylor.—I think I had better answer myself, as I made the test. Mr. Quimby's statement is generally true. We have had one sample of a reputable brand that tested 462 pounds. We have also had a cube—I am not sure whether it was of the same brand—that tested 5112 pounds. A great part of this difference is due not only to the cement, sand or stone, but a great part is due also to the way the concrete is put in the cube by the inspectors on the work. There is undoubtedly the same difference in the work as constructed.

Mr. Ellinger.—Did you test the kind of cement—not the brands—and what was the character?

Mr. Taylor.—All the cement of which the cubes were made passed the requirements of the Bureau of Surveys, which are pretty severe. The cubes were made by the inspectors on the work.

Mr. Ellinger.—Were the cubes made from cement taken from the shops on the work?

Mr. Taylor.—The cement concrete entering those cubes was the concrete that was put in the work They were not specially made from the cement itself.

Mr. Ellinger.—But that particular cement out of which the cubes were made was not tested by you—not the brand, but that particular batch of which the cubes were made was not tested by you?

Mr. Taylor.—No.

Mr. Ellinger.—That is the point.

Mr. Perrot.—I have said a great deal and the hour is growing late. The question of the reliability of concrete was one of the topics in the first part of my paper, and I do not think that in practice the uniformity of the mixture is as high as we should like it. That is the reason I think the values we use for reinforced concrete should be somewhat lower than what the carefully made tests give us. The formula used in figuring the strength of floors is based on a certain age of the concrete. We count on the concrete to develop the strength we want it to, according to formula, in six months. In other words we won't say that before the six months it is as strong as we claim, but in six months' time it will develop that strength. It may develop that strength before—in two or three months—but we are sure it is going to be the required strength in six. As Mr. Ellinger said, the variation of any particular brand is sufficient to make a wide variation in the ultimate strength. In the cement for a particular building we designed there were two carloads from the same manufacturer rejected. The cement that came from the works was uniform one week but not the next. Mr. Taylor knows that they have often rejected carloads of cement from the same brand. There should be a safeguard as to what cement should go in the work. As to the stone and sand, there is not so much danger, because that does not figure very largely in the binding quality. The cement is the vital point. If you get cement uniform, you generally have a concrete which will stand the loads which you want it to stand in practice. I know we have made mixtures for foundation work which have been very high in stone —as much as eight of stone, that is, 1, 4, and 8, also 1, 5, and 9, which have been perfectly satisfactory. We have made foundations 1, 2, and 4 which have been very rich. On an average, if you use 1, 3, and 5, I do not think you need have any fear, provided the cement will pass the test. There is a quantity of free lime in cement frequently, and if allowed to remain the cement will not meet the required test.

# NOTES ON BURNING BITUMINOUS COAL.

JOHN M. HARTMAN.

*Read February 6, 1904.*

THE following explanations are first given: tarry vapor, hydrocarbon, and smoke are in this paper spoken of as black gas—a rich gas of far higher heating power than the carbon. Bituminous coal will be spoken of as bituminous. The color-scale here referred to is a scale formed of one thickness of gray glass capable of cutting off 60 per cent. of a sixteen candle-power light, which represents No. 1 scale. Two thicknesses of said glass is No. 2 scale, and four thicknesses is No. 3 scale. In 1868, when the "bell and hopper" was first introduced at the top of the pig-iron furnaces to force the gas down to the boiler and stoves, difficulty was experienced in igniting the gas after a short stop of, say, ten to twenty minutes. This was obviated by placing a heavy fire-brick wall across the boiler chamber for the gas to impinge on, and absorb and retain the heat, which fired the gas and prevented explosions that had previously occurred. This heavy wall was also found to assist the gas in burning, and in making perfect combustion by breaking up the current of gas and mixing it thoroughly with the air. Bituminous consists of, say, carbon 82 per cent., hydrogen 5 per cent., nitrogen 1 per cent., oxygen 6 per cent., sulphur 1 per cent., and ash 5 per cent. Powder some of this bituminous and sprinkle it thinly on a red-hot plate, say, at 800 degrees; it gives off a thick black gas or tarry vapor with a strong bituminous odor. It is the hydrocarbon passing off at a low temperature. The quick liberation of this black gas causes the difficulty in burning bituminous, as it gets away from us before we heat it, ignite it, and make it do its work. To heat and ignite the black gas quickly is our duty. This can be done with heat stored up and replenished for that purpose. Sprinkle some of this powdered bituminous thinly on a glowing yellow plate, say, at a temperature of 2000 degrees; it ignites with a bright yellow flame which, seizing the free air around the plate, burns to a transparent gas—carbonic acid and water, without odor. The red plate develops a temperature of, say, 600 degrees; the yellow plate, say, 3000 degrees. The red plate means imperfect combustion, black

gas, and loss: the yellow plate means perfect combustion, a clear atmosphere, and thrift.

Take another plate heated to, say, 400 degrees, the temperature of the boiler water, and hold it over the red plate while the black gas is passing off, letting it touch the plate. The plate becomes coated with soot, which leaves a strong bituminous odor. This soot is one of the best non-conductors of heat, and destroys the efficiency of the boiler by clogging the tubes. Taking the yellow plate again and sprinkling a thick layer of bituminous over it, the flame arising burns on the exterior only, as the air cannot get at the interior of the flame until it has reached far above the plate, and by that time the gas has expanded, which lowers the temperature and it will not ignite. Hold the 400 degree plate over the flame; soot will collect on it. Taking the yellow plate again, sprinkle some of the powdered bituminous over it—a yellow flame outside and black gas inside appear; then hold another yellow plate above it, where the flame is black outside. The black gas fires and combustion takes place. The gas and air being heated causes a quick combination of the two. We have with the upper yellow plate added to the black gas the heat of ignition and fired it; it then burns to its full equivalent of heat. In place of the upper yellow plate, let us substitute a yellow fire-brick to absorb heat. This will give heat to the gas and air and fire them; the gas burning at a high heat gives back to the fire-brick the heat which it gave to the gas. The brick also receives heat, after gas is all driven off, by the radiation from the coke fire below, which is glowing white, and exposes the brick to its direct rays. As soon as the bituminous is put on again, black gas is evolved and heat is absorbed by it; but the black gas is burned clear. This interchange of heat continues as long as the fire is kept up. In burning the black gas this radiant heat from above is the most effective. As the black gas rises, it expands, lowering its temperature, and it is then supplied with heat from above, which ignites it and thus does not rob the fire below. Burning the gas in contact with the brick above it, heats the brick, causing more heat storage. The fire-brick acts as a fly-wheel to store up heat and give it out again. By this means the gas is kept burning continuously.

After the black gas is volatilized, the heat taken up in volatilization is carried up the chimney and lost, if the additional heat is not present to ignite it. This deficiency of heat robs the fire when it is weak and results in the evolution of more black gas and an increase in waste.

In the burning of bituminous there are three absorptions of heat before perfect combustion takes place.

First: the heat to liberate the black gas.

Second: the heat to supply the gas as it expands.

Third: the heat to ignite the gas.

This shows that a glowing hot fire and ample heat storage by fire-brick are required at all times for perfect combustion.

To burn bituminous in a boiler these principles apply as well as on the plates described. The first thing to be done with a fire is to nurse it carefully until it attains a white heat. After this, a high temperature is to be maintained by small additions of bituminous, for it is only at this high temperature that the full equivalent of heat in the bituminous can be obtained from it. Whatever color there is in the smoke at the chimney-top represents a loss due to the black gas not being burned in the furnace or fire-box. If the red plate develops one heat unit, the yellow would develop, say, 4½ heat units with the same fuel.

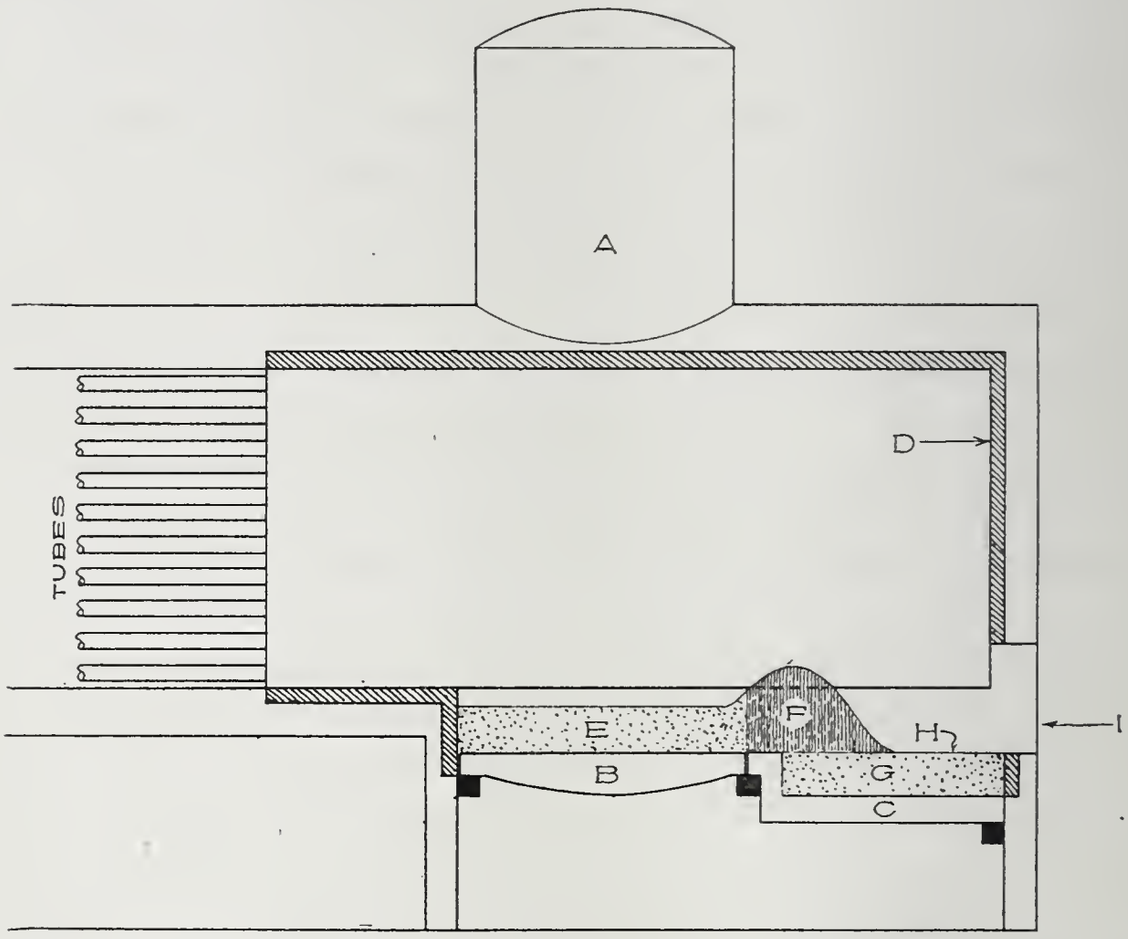
The air required to burn one pound of bituminous is about 150 cubic feet for combustion to carbonic acid, but in practice from 225 to 300 feet are used. This excess of air dilutes the heat of the fire-box and results in a loss. Much of this diluting effect can be avoided by heating the air, which will cause quicker combustion with both the coal and the black gas. Unless heated, this extra air does not get the proper time to combine with the black gas before it gets into the tubes, when further combustion is stopped by the tubes lowering the temperature below the point of ignition. Old firemen prefer to carry a thin fire and have all the air come up through the burning fuel. The only objection is that the engineer may open full stroke and tear his fire to pieces, if on a locomotive; hence the fireman has to carry a thicker fire than would otherwise be required, which makes more smoke. A check-valve at the bottom of the smokestack will correct this trouble. With a thin fire, more free air passes through the fire-bed, and being heated in its passage, it is in a better condition to unite with the black gas and burn it quickly. The regulation of the air is a serious question. When fresh fuel is added, black gas is evolved in large quantities, and an increase in the supply of air is required to burn it; but, the air being cold, combustion is checked to a certain extent; in addition, there are the three heat absorptions to further cool the fire. As the black gas is gradually driven off, less air is required. The air can be controlled by the fire-door being left partly

open and then gradually closed as the black gas decreases. When the fire is kept intensely hot, as it should be, the black gas will be burned before reaching the tubes. It is a question of the ratio of the calories in the fuel plus the heat in the furnace or fire-box, and the time required for the mingling and combustion of the air and black gas before they reach the tubes or water surfaces of the boiler, as to whether we will have perfect combustion or not. An intensely hot fire to give a short quick combustion is the requirement in burning bituminous. The oftener the bituminous is added, the smaller and more uniform will be the volume of black gas evolved per second and the more attention is required, but the fire will be more steady. Perfect combustion and heat absorption by the water surfaces cannot go on at same time and place; some black gas will escape unburned.

In starting a fire in a stationary boiler, wood is placed uniformly over the grate and fired all over, cheap or spent oil being used. The fire-doors are left open to give plenty of air and keep down the smoke. When the wood has burned off all its smoke, place on the wood the old coke left from the last fire and let it burn up; then add bituminous lump slowly, giving it plenty of air until it is well ignited, after which the air can be regulated to suit the fire. The fuel must now be burned at an intense heat; and by successive additions of a single shovelful, of about 18 pounds, must be kept at this heat. This will give an escaping gas at the chimney-top of No. 2 scale or under. In operation, the fire is kept of uniform thickness, except at the corners and sides, where it is kept a little thicker to prevent the air from passing up too freely. It will require attention every three to five minutes to obtain good results and as nearly perfect combustion as can be gotten with a plain grate, for the black gas evolved toward the bridge-wall or tube-sheet will, by the cooler water surfaces, be chilled below the point of ignition.

James Watt in his day, finding the smoke nuisance so great, pushed his grate bars back from the front about 18 inches and put a dead plate in this space. On this dead plate he placed a bank of bituminous that was heated by radiation from the furnace; part of the black gas being driven off, and escaping over the fire, was ignited and burned before it touched the water surfaces. When it was time to re-coal the fire, this bank was pushed over the fire evenly and replaced with a fresh bank. With the slow running of those days there was time to drive off the greater part of the black gas from the bank, but for the rapid running of these days better means must be had to get the

greater part of the black gas off in time for re-coaling. Where they used 60 pounds of bituminous per square foot of grate per hour, we use to-day 135 pounds successfully, and have little black gas from the chimney; but when we slaughter coal and use 180 pounds per square foot, we have immense volumes of black gas at the chimney and get no greater useful results than if we burned 135 pounds scientifically. The superintendents of the railroads have increased the engine end without caring for the grate end, and have piled work on the locomotive proportioned to the engine end.




A PROPOSED GRATE FOR BURNING BITUMINOUS COAL

Fig. 1.

A is an internally fired tubular boiler.
B is the main grate with shaking-grate arrangement.
C is the low-down grate with shaking-grate arrangement.
D is the brick lining of the fire-box.
E is the bed of coke burning on the main grate.
F is the bank of bituminous.
G is the bed of coke burning on the low-down grate.
H is the space for the escape of gas from the low-down grate.
I is the fire-mouth the whole width of fire-box.

When the bank of bituminous was pushed over on the fire, part of the black gas escaped at the chimney-top for one or two minutes, as the black gas in the interior of the bank had not been evolved. This arrangement was a help to prevent smoke, and is used to this day. Coking on the dead plate extends the time for re-coaling to, say, five shovels, and gives the fireman some leisure. These two methods of hand-firing are widely known and are not patented.

Another method by which a fire may be re-coaled so as to effect satisfactory ignition of the black gas is seen in the operation of the Hawley down-draft patent, consisting of a coarse inclined water grate placed over another grate inclined with bars closer together. Fire being started on the upper and lower grates, the bituminous is burned to coke, which is barred on the upper grate, and the smaller pieces passing the upper grate fall on the lower, highly heated, where they form a good body of coke. Bituminous being added to the top grate, the black gas is drawn down through the fire and fired in passing through the bed of burning coke on the lower grate. This grate works well, gives a high heat evaporative duty, but it requires work to bar the coke down to the lower grate and much attention on the part of the fireman. The chimney-top shows from No. 2 scale down to No. 0.

In hand-firing and machine stoking the first requirement is that the black gas shall be burned to carbonic acid and water, giving a clear chimney-top.

Second: the black gas must receive a full supply of air to burn it.

Third: the black gas must be burned before it touches the water surfaces or the tubes.

Fourth: the black gas must be evolved in time to burn before reaching the tubes.

Fifth: the air to burn the gas must be heated to obtain a high temperature and make a short burn.

To make it easier for the fireman in hand-firing and give a good combustion, a grate of the type shown in Fig. 1 is proposed.

The fire having been started on the two grates and burned to coke, a bank of bituminous is placed at F, where it is attacked below by the heat of the low-down grate, by the heat passing over it from H, and by the radiant heat from D, the fire-brick lining, and the heat radiated from B. Black gas is quickly evolved and supplied with heated air from the space H, where the fire is thin to allow extra air, or more than is required for the combustion of the coke in C, to pass it and be heated in passing. This extra air being heated causes quick

combustion, burning all the black gas before it reaches the water surface or tubes, where it would be cooled. Free air also passes through the coke at B and is heated. When the time arrives for re-coaling, a small portion of the coked bank F is scraped back into the space H to keep it full of coke and to give free passage to the air. The bank F is then broken up and pushed over the grate B, leveled, and another bank F made. This bank F holds back the black gas in its interior, letting it escape slowly and steadily, thus avoiding the necessity for large volumes of air at intervals, as would be the case if the bituminous were spread in a thin layer, resulting in a much quicker evolution of gas. The fire-mouth I has two doors covering its width. Re-coaling is done alternately at the two doors, thus getting the benefit of cross-firing. Driving the black gas off near the firing-doors gives ample time to mix the air with it before it reaches the water surfaces or tubes.

The fire-brick lining acts as an accumulator when the fire is at its height, by heat absorption before re-coaling. On re-coaling, the temperature of the fire is lowered, but the fire-brick gives out its heat and ignites the gas, keeping up thorough combustion. As the fire becomes hotter, the heat is again taken up by the fire-brick and stored for the next re-coaling; thus a continual interchange goes on with thorough combustion, which prevents the formation of soot on water surfaces and tubes, thus contributing to the perfect conduction of the heat through the tubes to the water. Steam is made cheaper from the tubes than from the fire-box. One square foot of tube is equal to four square feet of fire-box surface, considering average temperatures.

Perfect combustion in the presence of water-cooled surfaces abstracting the heat from the burning black gas and in contact with them is not to be had. To get it, all combustion must be made in the presence of fire-brick or other non-conductor, hence the necessity of the fire-brick lining to the fire-box in burning bituminous. Lining the fire-box may require a slight addition to the tube surface for the same work; it would not be much, as we get a hotter fire and cleaner surfaces. The presence of the fire-brick will make less free air necessary for perfect combustion than is now used. It will save the crown-sheet from cracking and help in case of low water. It will prevent cold air from cooling the gas and stopping combustion when the door is open for re-coaling. To line the fire-box requires no special appliances. This lining is firmer than the arch now used and is not disin-

tegrated by the coal, and while it is not so close to the fire, yet it does the work well.

To ask locomotive firemen to fire bituminous by hand and give good combustion without using fire-brick to ignite and burn the black gas is the height of folly; it cannot be done. No better proof is wanted than an examination of the records of railroads using the fire-brick arch and those not using it. The fire-brick arch in locomotives takes up and gives out heat when wanted to help combustion, and retards the black gas evolved next to the tube-sheet, giving it time before it gets over the arch to mix with the air. The arch does its work and pays well, but is somewhat difficult to suspend, and the attrition of the fuel disintegrates it in time.

What has been done to help the fireman who has an imperfect boiler tools and material—coal frozen in large lumps, etc.? He must make steam to keep up his speed. He gets poor pay; fires with his muscle, not with his brains; wastes coal; then we get well blackened and blame him for it. Genuine firemen are wanted, not coal-heavers who crowd the fire-box full of coal and then skip up into the cab and play with the bell while the locomotive is trying to digest her uncomfortable meal and is showering coal and smoke over the public. Genuine firemen should be licensed and protected. They save in coal more than their wages, besides saving the public discomfort. This is an age of specialists—the fireman has become one of them; we must recognize it. The position of fireman, properly carried out, requires as much skill and more labor than that of the engineer. Railroads are beginning to see it in that light.

The day is coming when the locomotive boiler will be a mass of tubes and the fire-box will be transferred to the tender; then explosions from the fire-box and crown-sheets will be ended and the trailer will be out of a position.

The following reports will throw some light on this subject:

PHILADELPHIA, PA., *Jan.* 12, 1903.

H. L. SHOCH, ESQ., *Chairman of Boiler Inspection.*

*Dear Sir:* On Thursday, September 25th, accompanied by Mr. Daley, member of the Committee, and Mr. Masterson, Secretary of the Committee, your Sub-Chairman went to New York to take a trip on the New York Central Railroad, and see the results obtained by the use of the "Perfection Burner" on the locomotive leaving 8.45 A. M. for Poughkeepsie with long Wagner or Pullman Parlor Cars. The distance covered was 74 miles and was run in 100 minutes. Through the courtesy of Mr. Waitt, Chief of Motive Power, your Sub-Chairman

was allowed to ride on the locomotive, and every facility was given him to see the operation of the burner, which is not patented.

The fire had been started as usual, with hard coal, to prevent smoke at the round-house while getting up steam, and to prevent smoke in the long tunnel from the depot outward. The distance through the tunnel—probably 2½ miles—is run at a moderate speed for safety. This hard-coal fire lasted for twenty-five minutes, by which time we were well out in the open air. A fair bed of coal still existed on the grate. The fireman then commenced building up the bed by adding fresh coal in small quantities often, until he got a good depth of coke. After this, by constant additions of soft coal about every three minutes, he kept and maintained this bed of coke at a white heat and with little smoke. About 95 per cent. of this smoke went off from the smokestack a light gray No. 2 color-scale. For a few moments after adding three small shovels of coal the smoke would darken to a dark gray No. 3 color-scale.

In firing he piled most of the coal just inside of the two firing-doors, but was careful to throw coal in any space in the bed of coke which showed signs of burning through and admitting air into the fire-box. Steam was kept uniform the whole distance, with only a small amount of blowing off at the safety-valve on one occasion, for a few seconds. Twice on the trip, after the coal lying inside of the fire-doors had the gas well driven off from it, the fireman took his rake and raked this coal over the bed of the fire; fresh coal was put inside of the door again. Once during the trip he shook the grate lightly to relieve the fire of the ashes. Throughout the trip there was perfect co-operation between the engineer and the fireman. Better firing would be difficult to get than there was on this trip. Nothing was done to help the "Perfection Burner," which was not changed or regulated during the trip. Only a small amount of steam is used in this apparatus to induce an air-current through the tubes over the fire-doors to burn the gas. The small valve to let in the steam was open one-eighth of a turn of the hand-wheel.

This gas-consuming apparatus consists of a fire-brick arch in the firing-box, and another arch over each of the firing-doors. Over those arches at the doors, jets of air, plus a little steam to induce the jet, are placed. There is no machinery attached to this burner. The fire-brick arch in the fire-box has been used for years and gives excellent results. The arrangement of the air-jets and arches over the doors is the new feature in this form of burner. No smoke was visible from the car windows of the train; while the trains running in the opposite direction and not equipped with the burner were rolling out great quantities of thick black smoke. The locomotives on the West Shore Railroad on the opposite side of the Hudson River were plainly visible, and gave out great volumes of black smoke. The New York Central Railroad is placing these burners on all of its locomotives, and on a careful test which they made, they found a saving of 12 per cent. in fuel.

Yours very truly,

JOHN M. HARTMAN, *Chairman Sub-Committee.*

PHILADELPHIA, *October* 22, 1903.

H. R. SHOCH, *Chairman Boiler Inspection Department.*

*Dear Sir:* On Monday the 19th inst. your Sub-Committee, Messrs. Hubbs, Masterson, and Hartman, went to Pittsburg and to Cleveland, to inquire into the operation of mechanical stokers and gather data on the smoke nuisance abatement.

On the morning of the 20th we visited the forge of the Oil Well Supply Company to examine a Jones Underfed Stoker at work on a forge furnace for heating 6-inch wrought-iron billets. We found them removing the clinker from the fire which had accumulated in six hours. They use bituminous slack, the run of the mine, which contains more clinker-making material than the regular market bituminous. After the clinker was removed the stoker pushed in a lot of fine bituminous which gave a dark smoke at the chimney-top for three minutes and then fell off to a clear top, at which it remained for six hours, or until the next clinker was removed. The interior of the furnace is at a glowing white heat. Since using this stoker they have doubled their output and bettered the quality, using the same men and the same amount of bituminous as with the old on the old hand-firing method. The stoker has been working fifteen months, in constant use day and night, and has cost nothing for repairs.

At Cleveland we were met by John Krause, Supervising Engineer, who went over their methods carefully and turned us over to his assistant, Mr. Woodward, who went around with us and showed us all the stokers which had given good results. At the city hall we found the boilers equipped with Jones Underfed Stokers, doing excellent work and giving a clear chimney-top. At the next place, the Davies or American Underfed Stokers, were giving a smoke at the chimney-top of No. 3 color-scale. The boiler-setting here was imperfect. At the same place they had another large boiler equipment with Chain Grate Stokers. These give good results in economy and a clear chimney-top when running with a steady load, but when extra steam is required the stoker gives a dark chimney-top. The next place had the Brightman Stoker. This had broken down temporarily and was being fixed. We waited until they started up, but the chimney-top was smoky. At this same place they had the Twin Arch Hand Fired Furnace, but it was not running. The water-tubes of the arch are too close to the fire for safety. At the next place they had a horizontal revolving grate, but its construction will necessitate many repairs. At the next place the Murphy Stoker was in use and was working well, giving good evaporative duty and a clear chimney-top.

In Cleveland they have 799 stokers at work, of which there are 27 distinct types. The majority are of the Murphy grate type, followed by the Jones Underfed, which is a later design and more simple in construction. After a careful examination it was found that three types of stokers have given the best results:

First: the Murphy Stoker.

Second: the Jones Underfed Stoker.

Third: the Chain Grate Stoker.

The Murphy stoker is adapted to externally fired boilers. It requires considerable space, and does not respond to sudden calls for more steam without a smoky chimney-top, and requires an average amount of repairs. With steady work it gives a clear chimney-top. It requires the fireman to break up the crust or coke on the bed of fuel from time to time. The grate is inclined on both sides and the coal is worked down on the fire by the movement of the grate. It delivers its clinker, which is broken up by the stoker.

The Jones Underfed Stoker is adapted to any form of boiler—puddling, heating furnaces, or locomotive. It has the smallest amount of machinery and occupies the least space and requires little repairs. It is flexible and responds to sudden calls for steam with a clear chimney-top. The clinker is removed by hand without stopping the stoker. This operation is the only manual labor required and is not difficult to perform. The crust of coke formed on all bituminous fires is in this stoker kept broken up by the ram pushing the bituminous in under the fuel and raising the fire. It gives high economy, a clear chimney-top, and the escaping gas contains only 0.33 per cent. of burning gas or combustible.

The Chain Grate is adapted to externally fired boilers. It has the most machinery and requires the most repairs. In regular, steady work, it gives good economy and a clear chimney-top, but when called on for extra steam it gives a dark chimney-top. Trials of this stoker at Pencoyd Iron Works, Philadelphia, showed a clear chimney-top with a steady load, but the economy was not so high as that of other stokers.

There is a marked difference in the atmosphere in Cleveland in the past four years. It is only half as dark as it was, notwithstanding the fact that the manufactories have doubled in number. While there are yet smoky chimneys, they are all to be corrected by the use of stokers which are contracted for but not yet delivered, by reason of the great demand for them.

The city of Cleveland finding it necessary to abate the smoke nuisance as much as possible, engaged Professor Benjamin to take up this subject and investigate it. He soon found, as did others, that the so-called smoke was combustible gas escaping from the bituminous and going up the chimney unburned, causing a waste of heat and power.

To burn this gas and use the heat could be fairly well done by hand-firing and exercising care, adding bituminous every five minutes. To burn gas economically and prevent all smoke at the chimney-top it was found that stokers were the best and cheapest. To fire by hand is light work, but it requires steady application of the fireman, while with the stoker the hopper is filled and will run twenty minutes or more without replenishing. With the stoker the fire is being constantly fed and an uniform steady fire is maintained without opening the doors, thus permitting large volumes of cold air to come in contact with the fire at a time when the air should be excluded.

Professor Benjamin then began a series of lectures and newspaper articles on this subject to get the people interested. In this he appealed to the manufacturers' pocket-books by showing them that they could save 10 per cent. on their coal, and appealed to the citizens for a clearer atmosphere. This agitation was kept up, and culminated in the erection of stokers at the city hall as an object-lesson, and finally by the appointment of a Bureau of Smoke Abatement, with John Krause as Supervising Engineer. This bureau has been backed up with the proper ordinances by the City Councils. Mr. Krause has taken hold of his work firmly, but exercises great care and judgment with his power in carrying on his work. Conciliation and not antagonism is his motto. His success is shown by the reduction of the smoke and the respect entertained for him by the citizens. His three inspectors are on the alert taking observations and classifying the smoke by a color-scale.

When Mr. Krause finds a determined offender, he invites him to his office and has a pleasant talk with him and explains what can be done. This always results in less smoke and the appliance of some means to further decrease it. A short time ago the locomotive firemen on the North Side became careless and showered volumes of smoke over the city. The inspector reported them and requested them to call on Mr. Krause. After explaining to them how to burn the bituminous properly and avoid smoke, they departed promising to do better, which they did, as they felt it would be a disgrace to be called up again and then fined.

The New York Central Railroad at Cleveland is using on its locomotives the "Perfection Burner" and making little smoke. This burner was mentioned in our report to you of October last, which stated that the smoke was No. 2 color-scale. The Erie Railroad is trying other methods, and all along the line there is shown an effort to reduce the smoke.

Mr. Krause's assistants gauge the color of the smoke by their eye and apply numbers to the density. Their reports are filed and can be referred to at any time. They show a yearly decrease in the smoke nuisance. The total expense of this bureau is $8000 a year. The population of Cleveland is over 400,000.

The stoker manufacturers install their stokers with a guarantee of saving 10 per cent. in fuel consumption, and in some cases have shown 25 per cent. saving. For hand-firing the Hawley Down-Draft and the Twin Arch systems are used.

Our thanks are due to Messrs. Krause and Woodward for their many courtesies and hearty co-operation.

JOHN M. HARTMAN,
*Chairman of Committee on Smoke Abatement.*

## MECHANICAL STOKING.

In the travels of the Philadelphia Smoke Committee they found three stokers that were perfectly reliable.

The Endless Chain Grate is the oldest. Eckley B. Coxe made later improvements, and brought it to its present state. The grate is made up of a series of short cast-iron bars linked together and engaging sprocket wheels at the front and rear ends of the grate, by the movement of which the upper portion of the grate is carried constantly forward. The bituminous is fed through a hopper of the full width of the grate, and the depth of the layer is regulated by a door which can be lifted or lowered. The coal is ignited near the front and is carried slowly backward, the speed of the grate being adjusted so that the time of travel is sufficient for the complete combustion of the fuel. The ash and refuse, being carried over at the back end of the furnace, fall into the ash-pit. The coke on the grate has to be broken up, from time to time, as it cakes. A fire-brick arch at the front end of the furnace facilitates the coking of the fresh bituminous as it enters, and the combustion of the volatile gas evolved. The apparatus, as a whole, is mounted on wheels and a track, and can be drawn out for inspection and repairs.

This stoker works well, but requires considerable repairs. It gives a clear chimney-top, but this is partly due to free air passing through the stoker. Its evaporation duty is medium. If called on suddenly for more steam, it does not respond quickly without producing a smoky chimney-top. It is applicable to an externally fired boiler.

In the Murphy Stoker the grate bars are arranged on opposite sides of the furnace and incline downward toward each other at the center the fuel being introduced at the top and fed downward toward the middle, in which there is a mechanical device for removing the clinkers. A fire-brick arch spans the combustion chamber. A coal magazine is located on each side of the furnace and is provided with discharge openings and coal pushers. The latter have a reciprocating motion imparted to each by a rocking shaft, rack and pinion. The inclined grate surface is composed of stationary and movable grate bars, alternately placed. The upper ends of the stationary grate bars abut against a compensating plate, which permits the bars to expand readily with the heat. The movable grate bars are connected to vibrating levers, from which they derive their motion. In connection with this motion the movement of the rock shaft imparts motion to the coal pushers in such a manner as to feed the coal just in proportion to the requirements of the furnace. The crushing and removal of the ashes and clinker are effected by a clinker bar at the bottom of the grates. The clinker bar is provided, on the outside, with teeth

which extend spirally around the bar, and the approximate inner edges of the grate bearers are provided with similar teeth, to aid in crushing the clinkers when the clinker bar is rocked. The furnace is especially adapted to the use of bituminous slack, which is put into the magazines at the upper part on the sides of the combustion chamber. Air is admitted through a register at the front, passing through flues up over the arch, and there taking up heat from the front arch and arch plate, then passing down through the small openings in the arch plate to the coking fuel.

On the side of the battery of boilers is placed an engine with gearing for operating a reciprocating bar across the outside of the entire front, and to which all the working parts are attached by links. With steady work this stoker gives a perfectly clear chimney-top. The crust of coke has to be broken up by the fireman from time to time. This stoker requires more space, has more machinery, and is more costly than the other stokers, but it gives a clear chimney-top, delivers its own ashes and clinker, which accounts for more machinery. It is adapted only to externally fired boilers. This stoker can be seen at Strawbridge & Clothier's warehouse, Eighth and Race Streets. The chimney-top is perfectly clear when using Westmoreland bituminous, which is extra smoky, being a gas coal.

The Jones Underfed Stoker consists of a steam cylinder or ram, with a coal hopper, outside of the furnace proper; a retort or fuel magazine inside the furnace, on the sides of which are placed tuyere blocks for the admission of air. The retort also contains, at its lowest point, an auxiliary ram or pusher, which causes the coal to be evenly distributed. This pusher is in a position where the fire never reaches. The retort is first filled with coal on a level or a little above the tuyeres. The fire is then started along each side of the retort, the air-chambers reaching to the tuyeres being open. As soon as the fire is well under way, the air-chamber opening is closed and the blower started; the fire will then burn up rapidly. The hopper being full of fuel, bituminous slack preferred, and the ram plunger on its forward stroke, when more coal is needed the plunger is shifted back by moving the lever; coal then falls in front of the plunger, steam is admitted to the cylinder, and the plunger is forced forward, pushing the coal into the retort. Coal is pushed into the retort as needed to replenish that which is consumed.

Air at a lower pressure is forced into the air-chamber and through the tuyeres over the top of the fresh coal in the retort, but under and

through the burning fuel; the result is that the heat from the burning fuel over the retort slowly liberates the black gas from the fresh fuel. This black gas being thoroughly mixed with the incoming air, before it passes through the burning fuel, results in a bright clear fire free from black gas. The retort being air-tight from below and the fuel being in a compact mass, the air moves upward and combustion takes place only above the tuyeres. The retort is thus kept cool and is not subjected to the action of the fire. The incoming fresh fuel from the retort forces the ash and clinker over the top of the tuyeres on to the side plates, from which they are moved easily and without interfering with the fire in the center of the furnace. Each time the ram pushes feed into the retort it pushes it upward at the same time; this action breaks up the crust of coke formed on top of the retort and eases up the fire in place of doing it by hand. As the black gas is liberated below the burning surface, it is heated and ignited by the burning surface of the fire. No cold air enters the furnace during stoking.

This stoker is applicable to externally and internally fired boilers, including those for locomotives. It gives a clear chimney-top, but uses an excess of air, unless the black gas is burned with a fire-brick arch, in which case it gives perfect combustion with no excess of air and a high evaporation. The fan supplying the air to the stoker is controlled by a valve, which when steam goes down admits more steam to the fan and stoker, thus starting them up faster and keeping up the steam. This stoker can be pushed up without producing smoke at the chimney-top, and it is the only stoker that can be applied to a locomotive. The fan used for stationary stokers would be replaced with an Argand blower. While the steam used in the blower will be mixed with the air going through the fire, which is not economical, yet there are advantages gained from it. With the Argand blower there will be no back pressure on the steam cylinder, crippling the exhaust. The fire being under pressure, the heat will be packed in the tubes and every square inch utilized. Boilers with heat under pressure always steam better than with suction for draft.

One of these underfed stokers was put in the end of a heating furnace at Pittsburg, replacing the old fire-grate. The furnace heated 6-inch wrought-iron billets. In place of the thick black smoke formerly escaping, the chimney-top is as clear as the air. The heating chamber is a beautiful glowing yellow at all times. With the same fuel and men, they are turning out twice the amount of work and of better quality, as the heat is so uniform and intense. This stoker has run eighteen

months, and has required not a cent for repairs. It is adapted to puddling and other furnaces, which shows how perfectly it can burn bituminous without smoke and yet get the full equivalent of heat from it.

## DISCUSSION.

John M. Hartman.—A little explanation with regard to the color-scale is required. The committee on the smoke ordinance have been trying to chop the bill to pieces. The last thing which they did was to cut off the No. 1 scale entirely, and move up the numbers so that the former No. 1 was stricken off, and the former No. 2 becomes No. 1. There has been a great amount of trouble with the bill. For twenty-one months it has been fought over and everything has been done, that was possible, to get a satisfactory bill through. At Cleveland they have done more than at any other place. They took hold of the subject in the right spirit, and have now better laws regarding the smoke nuisance than any other city or town in this country. We have, if our recommendations are adopted, a color-scale that is fixed: none of the others has. They simply judge by eye. If we can succeed in getting the bill through we will be in a better position to prevent any juggling with the inspector. He has a scale by which he can determine what is the proper color. Chicago has a long law, by which it is difficult to define "thick black smoke or dense gray smoke," but it is a fact that a black gas escaping above our No. 3 scale is a gas that you can burn. This being the case, it is evidently wasteful to permit it to escape. Most of it is carbonic oxide, which is very poisonous, killing all vegetable life, as can be seen in going along the Pennsylvania Railroad, where it has killed or stunted the trees and shrubbery that are close enough to the track to be affected by it.

James Christie.—I am sure we appreciate Mr. Hartman in his study and investigation of the problem of preventing smoke.

Notwithstanding the frequent statements that this problem is a comparatively simple one, and that the issue of black smoke can be prevented by a little care, yet the experience of all communities that use bituminous coal demonstrates, on the contrary, that the problem is an exceedingly difficult one, especially when it is remembered that we must not unduly hamper or place a heavy burden of expense upon the industries to be dealt with.

It has been evident, for several years, in our seaboard cities, that the tendency is for bituminous coal to become cheaper and anthracite to become dearer. We know that the anthracite deposits are of such a limited extent, as compared with the bituminous, and that the development of the means of transportation, especially from the West Virginia fields, are so favorable to the use of the latter fuel, that it is probably only a question of a few years before bituminous coal will be the predominant fuel in our city for manufacturing purposes, and, possibly, to a large extent for domestic use; therefore, to prevent Philadelphia from becoming a smoky and uncleanly city, comparable to those in which bituminous coal is entirely used, it is necessary for us to have reasonable and practicable city ordinances on the subject, which will govern the conduct of the careless and indifferent without embarrassing those who make a reasonable effort to prevent the issue of smoke. If there are no regulations on this subject and the

consumer is allowed to burn bituminous coal in any manner that to him seems the most easy and expedient, we will then have a smoky city, as has been abundantly illustrated elsewhere. If, on the other hand, we have well founded laws and regulations whose intent should be to instruct the consumer, without seriously annoying him, we will be on the best road to reach the desired solution.

There are two systems for the hand-firing of bituminous coal, which, if faithfully pursued, do prevent the issue of black smoke. These methods are usually known as the "Sprinkling System" and the "Coking System." Both of these methods have been in use, more or less, for over a century. By the sprinkling system, firing is performed at frequent intervals and small quantities of fresh coal, at a time, are scattered over the fire. By the coking system, the fresh coal is piled at the fire mouth and pushed back and spread over the incandescent mass in front of it, after it is coked. It is also well known that both of these methods entail either loss in efficiency or increased labor to the fireman. The sprinkling system, as performed by hand, is usually attended by loss; inasmuch as the fire-doors are opened too frequently and large quantities of cold air sweep through to the chimney. By the coking system, increased labor devolves upon the fireman, as it prevents free access to the body of incandescent fuel for cleaning, removing clinkers, etc., and consequently it is usually difficult to enforce either of these methods, especially if the fireman is overworked by the pressure of his duties.

These methods of firing are successfully accomplished by the means of mechanical stokers, especially the coking system, which is the most customary method, and the various methods of mechanical stoking in vogue, are based on the principle that fresh fuel is applied by increments, and that the volatile gases, which pass off at the early stages and which carry the black smoke, are either passed over, or, preferably, through the mass of incandescent fuel, where the temperature is raised to such an extent that complete combustion ensues. This object is accomplished, with practically similar results on the under-fed, the horizontal-fed and on the down-draft systems: they all give nearly the same final results when properly applied. It is now sufficiently demonstrated that, with a good system of mechanical stoking, bituminous coal can be successfully and economically burnt with little, if any, visible smoke in the discharging gases, and the city should have, in all of its departments, the best apparatus of the kind to be found, as an object-lesson to which the citizens can be directed for information. We must remember, however, that even if smoke is prevented from our manufactories, the use of bituminous coal for domestic purposes may, hereafter, and probably will, create a nuisance, and we cannot put mechanical stokers in all of our houses. Probably a convenient adaptation of the magazine system would present one solution of the problem, but it is likely that other methods of preparing fuel for domestic purposes would prove the most convenient method, and we can refer to the successful use of briquetted coal, now so largely adopted in Germany. The establishment of large bi-product coke ovens, in the vicinity of cities, would yield an abundant supply of coke, but, while this coke would be desirable for foundries or similar industrial establishments, it is not a convenient fuel for domestic purposes. It is too light and bulky and crushes too readily into dust.

Another solution is the introduction of cheap fuel gas, and it is probable

that, in the not distant future, the homes of our cities may be supplied with this cleanly and convenient method of heating.

Emile G. Perrot.—Will Mr. Hartman give his reasons for making the statement that a furnace with a forced draft will produce more steam than one with an induced draft?

Mr. Hartman.—A reply to this question will be made from some practical experience. At the Merion Furnace at Conshohocken, where a "bell and hopper" was first put on, they were short of steam. After the "bell and hopper" was in place, the gas was forced down to the boilers and there was a noticeable tendency for it to escape through any leaks at the doors. In looking into this matter it will be noted that where there is a suction, the tendency to cut across corners is so great that the full benefit of the contact of the gas with the boiler surface is not obtained. We know that when a flask is placed in the chemist's sand bath, the sand covers all around it and up over it; the result being that the glass does not crack but heats quickly. The same principle applies to forcing the gas in through the tubular boiler. There are no short cuts and the gas is packed up tight against the surfaces so that it has something to act on. There is no tendency to produce irregular drafts through the furnace. With this forced draft the fireman would have a little more gas in his room; but still he could regulate the damper to prevent it.

E. M. Nichols.—Some years ago I had occasion to look into the matter of burning bituminous coal without making smoke; and I spent a good deal of time on the matter. I have taken coal from a certain mine, one car of well screened lump, another car of what is termed "nut coal," about the size of anthracite nut, and both mined the same day. The nut or pea coal was burned on a chain grate stoker, quite similar to the one Mr. Hartman has described to-night—attached to a battery of two boilers. The lump coal was hand-fired under another battery of boilers standing alongside of it. The conditions of the boilers, so far as their setting and draft were concerned, were identically the same, but their grates were different. I made several simultaneous tests on the two boilers, with the conditions as nearly alike as possible, placing the best fireman I had in my employ to handle the lump coal, and with a perfect imbecile (this was in a large insane hospital) taking care of the chain grate stoker. I succeeded in burning at least 25 per cent. more fuel with the chain grate stoker than I did by hand-firing, and, pound for pound of fuel, I evaporated 15 per cent. more water, notwithstanding that the boilers were forced to at least 60 per cent. above the nominal rated capacity with the chain grate stoker. We had from the chain grate stoker boilers, as Mr. Hartman would say, a "clean chimney top," while with the others we did not.

My experience with the chain grate stoker leads me to believe that fires can be forced to respond to sudden demand about as quickly as with hand-firing and without making an appreciable increase in smoke. When a fire is forced with bituminous coal it seems almost impossible to avoid some smoke. There is another method that can be adopted with hand-fired boilers, which will prevent, to a large extent, the making of smoke; that is, by bringing the grates further in front of the boilers and setting them somewhat on a slant downward towards the bridge wall, with a long fire-brick arch covering the whole grate; some-

what on the plan of a reverberatory furnace. With this system after the fire has once become bright, it is almost impossible to make it smoke.

I believe that I can take nine out of ten boilers in the city of Philadelphia to-day and re-arrange their grates at a very small expense, so that if the fireman will take any pains at all he can reduce the amount of smoke that would be ordinarily emitted fully 75 per cent.

There is another point that has been touched upon regarding the utility of forced combustion, and upon which I would like to say a few words in addition to what Mr. Christie and Mr. Hartman have said on that particular point. The absence of smoke does not always indicate economy, so far as combustion is concerned; neither does the presence of smoke always indicate any great loss. In order to secure economical combustion of coal, the carbon must be distilled into the gases, which combine with the oxygen of air in the proportions one and two. In the former we get carbon monoxide; in the latter we get the carbon dioxide which is twice as hot as the monoxide. The more forcible the admission of air, the quicker and more thorough is apt to be the mixture of the gases; and the sooner it is obtained, the smaller is the proportion of air with the carbon, and while the carbon may all be consumed as the dioxide, the proportions of air used are so great that the nitrogen dilutes and cools it very much.

The economy with forced combustion is brought about by securing much more quickly a thorough mixture between the oxygen in the air and the carbon; when this mixture is completed in the presence of sufficient heat, then we get a smokeless combustion, but if the mixture has not been secured before the gases reach the boiler shell, many of the volatile pieces of carbon are likely to pass off as black smoke, but it can hardly be called economy if the forced draft is so great that part of the gases are forced out through leaky boiler settings.

Holstein de H. Bright.—I would like to ask Mr. Hartman a question about the Jones Underfed Stoker. Is the fire concentrated and is it higher and more intense in the center, thereby endangering the tubes located centrally over each stoker?

Mr. Hartman.—From what I have seen of this stoker, the fire appears to be well distributed. The tuyeres on each side are some distance apart and there is not an intensely hot section of the fire at the center; it is pretty well distributed and the tendency is, as the coke is broken up by the operation of the ram in forcing in fresh coal, to spread the fire to each side. The coal coming up from below forms a core in the center that will not fire so quickly as the part nearest to the tuyeres, and combustion is thus retarded. I have seen no cases where a flue or tube has been burned.

Mr. Hartman.—There is nothing further to say. All that can be asked of my fellow-members is to give us a little encouragement in fighting for the smoke bill, for we have not been on a bed of roses by any means.

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The following ordinance, passed since the presentation of the preceding paper, is appended at the request of Mr. Hartman, who states that "it is not perfect, but is the best to be had and will do for a beginning."

AN ORDINANCE.

To regulate the emission of smoke from chimneys, stacks, flues or open spaces within the City of Philadelphia; providing a color-scale for the measurement of the degree and darkness of such smoke; making it unlawful to permit the escape of smoke of certain degrees of darkness and providing a penalty for the violation of this ordinance.

SECTION 1. *The Select and Common Councils of the City of Philadelphia do ordain*, That for the purpose of regulating the emission of smoke from chimneys, stacks, flues or open spaces within the said City, and to determine by comparison the degree of darkness of smoke so emitted a color-scale shall be, and the same is hereby, adopted as follows:

One thickness of gray glass of sufficient capacity to cut off sixty (60) per cent. of the light from a flame having a lighting power of sixteen (16) candles, shall be taken as the basis of this scale; two thicknesses of said glass shall be known and designated as No. 1 scale; four thicknesses of the said glass shall be known and designated as No. 2 scale.

SECT. 2. It is forbidden and hereby declared to be unlawful to suffer or permit the emission or escape of smoke from any or all fires not in motion, or fires banked or in a state of rest, or from any burning or active fire through a stack, flue or chimney less than fifty (50) feet high of a color greater than No. 1 scale.

SECT. 3. It is hereby forbidden and declared to be unlawful, within the limits of the City of Philadelphia, to suffer or permit the escape or emission of smoke of a degree of darkness in excess of scale No. 2, for a period of more than five (5) consecutive minutes, from any locomotive or river steam craft standing with banked fires or engaged in shifting; or for a period of more than ten (10) minutes from any locomotive or river steam craft whose fire may be in process of cleaning or preparing for starting. *Provided, however*, That none of the provisions of this ordinance shall apply in the case of a locomotive, or locomotives or river steam craft, in continuous transit through, or across the City, or entering or departing therefrom.

SECT. 4. It is hereby further ordained that smoke may be suffered or permitted to escape from any puddling, open hearth, or forge furnace now erected of a degree of darkness not exceeding No. 2 color-scale, through a chimney fifty (50) feet high, and from any puddling, open hearth, forge or other furnaces hereafter erected of a degree of darkness not exceeding No. 1 color-scale with a chimney not less than one hundred and fifty (150) feet high; but that the emission or escape of smoke of a color degree of darkness greater than that provided respectively in this section is hereby prohibited and made unlawful.

SECT. 5. It is hereby further ordained that no fumes of a sulphurous or obnoxious odor occasioned by the melting of scrap-tin or other metal, shall be permitted to escape from any foundry or furnace within the built-up section of the City.

SECT. 6. The provisions of this ordinance shall not apply as to the color of smoke between the hours of 4 A. M. to 7 A. M.

SECT. 7. Any person or persons who shall violate any of the provisions of this ordinance, or suffer or permit any of the acts hereby forbidden or declared

to be unlawful, shall be subject to a penalty of twenty-five (25) dollars for each offense, such penalty to be collected and recovered by and at the suit of the City of Philadelphia for the use of said City, as debts of like amount are now by law recoverable. *Provided, however,* That any suits for the violation of the terms of this ordinance must be brought within five (5) days after the offense shall have been committed; and within forty-eight (48) hours after the commission of the offense, a notice shall be mailed to the offender by the Bureau of Boiler Inspection notifying the offender of the violation of this ordinance and the details of such violation.

Sect. 8. The provisions of this ordinance shall become operative and effective on the 1st day of October, 1904, and the enforcement of said provisions shall be, and is hereby, made the duty of the Bureau of Boiler Inspection, subject to such incidental rules and regulations as the said Bureau of Boiler Inspection may establish and provide.

# CONFLAGRATIONS IN CITIES.

A Topical Discussion, March 5, 1904.

HENRY LEFFMANN.

Engineers can probably learn as much from fires of moderate size as from those that devastate a large territory, but human temperament is such, that great catastrophes are needed to attract general attention. The Chicago theatre fire led to examination of the conditions of safety and fire-prevention in theatres all over the world; the Baltimore fire drew widespread public attention to the insufficiency of modern municipal construction.

As an introduction to the discussion of the whole subject of fire-prevention and fire-control in cities, I have been assigned the honor of exhibiting some lantern slides illustrating prominent features of the Baltimore ruins. It may be of interest before proceeding with these to exhibit a slide showing the approximate comparative area of some noted conflagrations, as follows:

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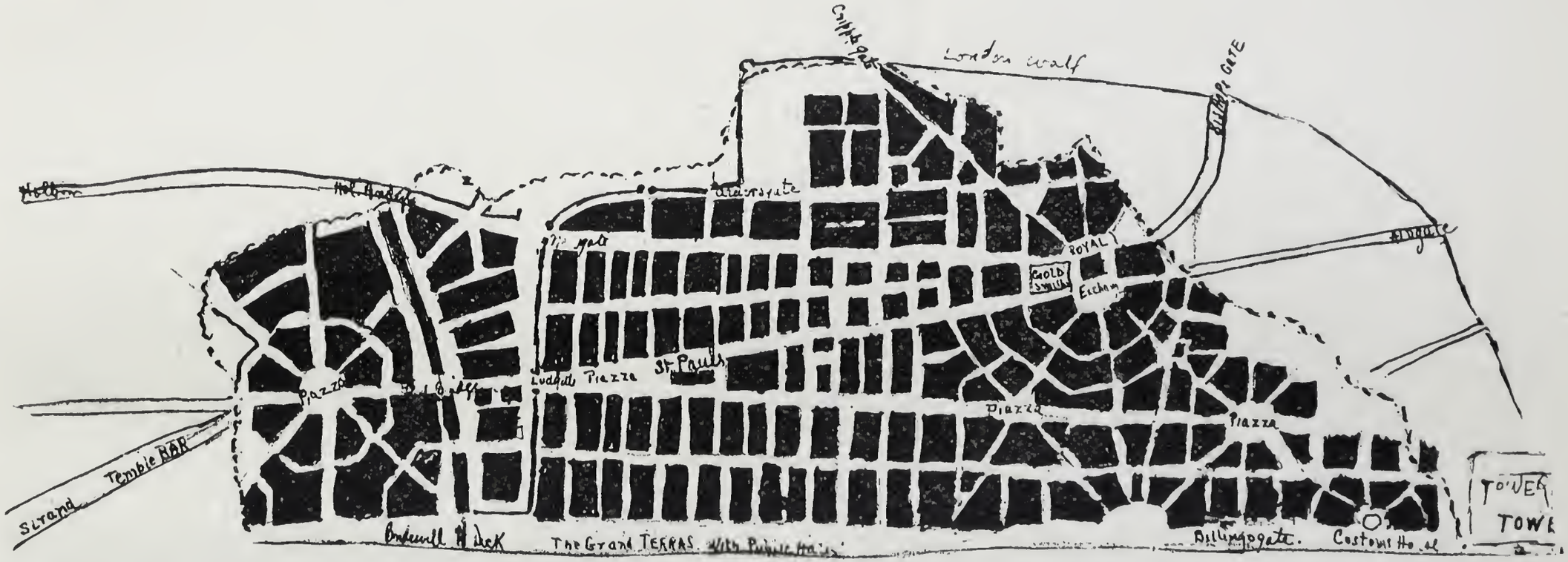
|---|---|
| Chicago, 1871 | 2000 acres |
| London, 1666 | 375 " |
| Baltimore, 1904 | 14 " |
| Boston, 1872 | 65 " |
| Philadelphia, 1850 | 13 " |

Of course, these figures show only one of the many points of comparison. The total monetary loss in each case would not coincide with the above data; moreover, the fire area should be compared with the total area of the city. Thus, the area of the Philadelphia fire of 1850 represents a much larger ratio of destruction than the figures given indicate. The Chicago fire, even under such allowances, would still be the largest area definitely ascertained. The London fire stands next, and there is a special engineering interest attaching to it, because Sir Christopher Wren proposed a plan for rebuilding, which if accepted would have greatly improved the city, and anticipated, by many years, some of the methods of modern municipal improvement. In spite of the assistance of the government, the great architect was unable to secure the acceptance of his plan by the citizens. Through the courtesy of Dr. William Beam, I have secured a rough copy of




Rough Copy, Made by Dr. William Beam from Map in British Museum, Showing Sir Christopher Wren's Plan for Rebuilding London after the Great Fire. The dotted line shows the limits of the burned area. The plan was not adopted by the citizens.

this rebuilding plan from a map in the British Museum, and will exhibit a lantern slide of it.

I will leave to others to discuss the engineering inferences to be drawn from the Baltimore ruins, but I wish to call special attention to certain slides that show the great danger from overhead wires, not only from their general entanglement obstructing the progress of the firemen, but also the liability of them to cause fatal shock.

A point that deserves consideration is the value of wire-glass as a fireproofing material.

## GENERAL DISCUSSION.

William McDevitt.—Mr. Chairman and members of The Engineers' Club: This subject, I am sure, should be a very appropriate one for this organization, and I hoped when coming here to-night to hear the opinions of some of you who may have visited the Baltimore ruins, regarding the effect of the fire and resistance offered by the modern fireproof buildings.

In walking over the ruined streets it was hard to recall to mind the once busy thoroughfares that are now lined with heaps of waste, and one particular feature noted was that, among the few spectators, there was an absence of those who had occupied the burned buildings, which no doubt was owing to the sickening sight presented to them and also the gloomy outlook for the future. Baltimore has a fire department of size proportionate to the size of that city, and I personally know of several threatening fires occurring there which extended to two or three buildings, but the fires were conquered just as we have seen here. The fire service is composed of about twenty-five engines and other apparatus manned by three hundred men. We have in our city double the number of apparatus and also the number of men.

The recent Baltimore fire looked insignificant at first. It occurred in a building six stories high and about 100 feet by 140 feet, occupied as a dry-goods store. The firemen broke into the building and found the fire burning in the cellar, and upon attempting to fight it they were driven back by the smoke, which was being carried up an open hatchway, which served as a chimney, to the upper floors. Water was then directed from the first floor down the open hatch. Suddenly, there was a violent explosion from the upper part of the building, which forced the men out of the doors, and at the same time burst all of the windows above and directed a flame of fire across the street, setting the buildings opposite on fire. The chief of the fire department informed me that within six or seven minutes seven buildings fronting the Hurst building, wherein the fire originated, were all on fire.

My errand there was to investigate the cause of explosions, which were all explainable. In about fifteen minutes after the fire had enveloped a number of buildings a terrific explosion was heard, which had the tendency to demoralize the firemen for a while. It was said that this explosion came from powder, the report being heard all over the city. In company with a resident of Baltimore I was taken over the ruins immediately in front of the Hurst building, where a building formerly occupied as a hardware store stood. In front of the building,

on the sidewalk, there had been a magazine of gunpowder. The law of that city requires that all gunpowder must be kept outside of the buildings where sold. A member of the hardware firm admitted that the powder was there at the time of the fire, and it was said that the explosion blew in the front of that building and sent burning embers in all directions. We can imagine what the conditions were at the early stage of the fire. The chief informed me that in less than one hour he had given up the idea of checking the fire and called for aid from other cities. Within the time one whole block was well on fire the burning embers could be seen carried by the wind blocks away, where other fires were started. In the path of the fire were several buildings of modern fireproof construction, but the people who built them never expected such an exposure to fire as they were subjected to. These high buildings, I was informed, took fire when the sweep of fire was several blocks away, a feature that is easily explained, as we had in our city fires on Arch and on Market Streets, where the heat extended across the street and set fire to window-shades inside and left the window-glass intact. That can happen with a temperature of seven or eight hundred degrees, but it would be hard to estimate the temperature of the heat from the Baltimore fire, with six or seven blocks burning; it must have been at least 1500 degrees, and the high buildings, with walls pierced with windows, were an object for the heat from the most fierce combustion, judging from the absence in the ruins of a single stick of wood. A fire, occurring within one of these high buildings, would not affect the structure much, but in the Baltimore fire they were enveloped in a terrific wave of fire and heat.

The damage to these modern structures is being calculated by a committee of insurance engineers. It has been said that such a fire could not occur in our city, but such a statement is misleading, as we have had one or two fires in our city which, if occurring on Sunday or in the middle of the night, might have resulted in such a calamity as that of Baltimore. During the burning of the Hirsch building, opposite Wanamaker's, a few years ago in the daytime, the heat from that building affected buildings two hundred feet off, setting fire to them, but you could see the people, who fortunately were inside at the time, extinguishing the fires. At that fire, although the wind was northwest, the heat broke the window-glass in the City Hall at a distance of 200 feet. It would be hard to imagine what the result would have been if the fire had occurred at a time when the buildings were left to the mercy of burning brands.

We show the superiority of our fire-fighting appliances as compared to that of foreign countries, but our trouble comes down to building construction. In many instances of fires it is the building that makes the fire, as often we have fires in a five- or six-storied building which has been gutted and we got thirty or forty thousand dollars' worth of goods from the ruins, as the interior of the building tumbles down before the contents are burned.

The explosion which occurred in the Hurst building in Baltimore, wherein the fire started, resulted from an accumulation of gases in the smoke. The firemen stated that the building became darkened and the smoke coming down from the upper floors became ignited. These "smoke" explosions generally occur at an early stage of fires, but just as soon as we get water on the fire and steam is produced and is carried up to the cloud of smoke, the explosive mixture is dampened and the ignition of the gases is prevented.

Wm. Copeland Furber.—I have visited Baltimore twice since the fire and, while there, was very much interested in studying the behavior of the modern fireproof buildings under the conditions which prevailed during the recent conflagration.

The damage suffered by these large fireproof buildings was surprising, and their behavior was, at first glance, distinctly disappointing. I had expected that such buildings as the Calvert and the Equitable, and other high buildings of similar construction, would have offered a check to the flames, but they now stand as blackened ruins in a broad swath of desolation and waste. It is only when we realize that they are still standing, when all other buildings of other forms of construction are piles of debris, that the sense of disappointment at their disfigurement is modified by the appreciation of the fact that they are still upright and apparently sound structurally.

When these costly and monumental structures are examined in detail and the destruction of their wealth of marble and bronze and other elaborate fittings is perceived, one cannot but be impressed with the utter waste of what was intended by the designers to be imperishable, and have a feeling of sympathy for those who suffered from the loss of what they deemed a permanent investment.

I made a very careful examination of the Calvert Building—a modern fireproof structure of superior construction—upon my first visit to Baltimore. I found from top to bottom hardly a bit of combustible material left. The sleepers in the concrete filling over the top of the tile arches were completely burned out. The glass electric light bulbs, bottles and other articles of glass had melted and run into shapeless masses or little pools. This melting of the glass indicated a temperature of at least 2500 degrees Fahr. All the floors of the building were completely gutted, most of the partitions were down, though I believe that many of these partitions were thrown down by the concussion caused by the explosion of dynamite which was used in wrecking buildings in the attempt to create fire-breaks to stay the progress of the flames.

The Calvert Building is, I should say, about one-half the size of the Drexel Building, Philadelphia, and outside of the walls and the hollow tile floors and the skeleton, nothing of value remains. The hollow tile arches are intact on the tops, but in many cases the lower sides of the tile have fallen off and the floor is covered with parts of this tile which seem to have lost all of their structural value and have about the same consistency as dried mud. I do not know what the particular composition of this mixture of fire-clay was, but I cannot believe that it was a proper one, or I am sure it would have been able to pass through such temperature as this without material injury; as I have made a number of tests of porous fire-clay hollow tiles, heating them to redness and plunging them into water without apparent injury to their structural properties.

The exterior walls of this building are greatly injured by the flames, and much of the ornamental terra cotta is completely destroyed for architectural purposes and will have to be replaced. The skeleton is apparently uninjured; the only injury apparent being one of the columns on one of the upper floors, which was buckled because the fireproofing had been broken off. That the damage was not greater than it was, is surprising, when it is realized that the fire swept completely through the building from side to side on every floor.

The Equitable Building, which adjoins the Calvert Building, is not a fireproof structure of the most approved type; indeed, the damage it has suffered is sufficient to show that it was very defective in many respects. It is at present in a serious condition, and careful examination of the skeleton will have to be made to see if it is not greatly injured. Many of the floor beams and girders are bent and twisted. The floor construction seems to have consisted of segmental terra cotta arches without protection to the lower flange of the beams, and above this a thick plank floor was placed, with no filling over the arches or under the floors. When the wood floor burned out, I am informed that the fireproof safes in the offices, having nothing to rest on, toppled over and crashed through the floors and broke many of the arches and bent many of the beams. When I first saw this building, I asked permission of one of the guardsmen to enter it, and he refused, saying that it was not safe. I replied that I was willing to take the risk, if he gave me permission; before he had an opportunity to make a reply, a safe fell from one of the top stories, crashing through floor after floor, accompanied with flying debris and raising such a cloud of dust that I concluded that the guardsman was right and I did not press my request further.

The Court House opposite the Calvert and Equitable Buildings was not seriously injured, except on one corner, where the marble is spalled and cracked. That this building escaped seems like a miracle, as all the buildings on two sides of it were either destroyed or burnt out. I am informed the little damage the Court House sustained was largely due to the efforts of the employees, who kept streams of water playing over the faces of the walls and windows, and whenever any of the woodwork around the openings took fire immediately quenched it with water.

In looking over the burned area in Baltimore, one cannot but be impressed by a sense of desolation and waste and by a feeling of regret that the works of man cannot be made more durable; yet when the problem of the prevention of this fire waste is studied as a whole, the reason for the failure of these modern fireproof buildings is made apparent and the defects in their design become obvious. No building of any reasonable construction can be said to be fireproof when its walls are pierced with many windows of fragile glass fastened in wood sash and wood frames. This defect is still further augmented when the floor plan is such that three or four sides of the building are so exposed, with no firebreak in the shape of a solid wall to prevent a draft through the building from side to side. It has been pointed out here to-night by one of the speakers that wire glass windows will not prevent the ignition of window-shades and other inflammable matter on the inside of such a window, even though no opening exists for the entrance of the flames, as in a conflagration the radiant heat is so great that the glass offers no barrier to these rays.

Mr. S. Albert Reed ("Journal of the Franklin Institute," November, 1896) estimates that the temperature of a fire in a lard refinery at 59th Street and Eleventh Avenue, New York, was 5000 degrees Fahr., and with such a temperature as this, the radiation to the adjoining properties would be dependent upon their distance from and the exposure to the source of the fire. Wire-glass windows would not prevent such temperature as this from affecting inflammable material, but if by maintaining their integrity they prevented a draft of air from increasing the combustion within, and sweep of the flames from without, it

would still be possible to employ human intervention or automatic sprinkling devices to prevent combustion and reduce the internal temperatures. A careful examination of the walls of these large office buildings still further emphasizes the necessity of keeping the window openings closed, as a large part of the damage to the walls of these buildings seems to have come from *within the buildings* themselves and *not from without.* Wire-glass windows with the assistance of automatic sprinklers would no doubt have prevented a great deal of this damage, as was illustrated to a degree in saving the Court House by water properly and intelligently applied by hand. It is highly probable that the radiant heat ignited the wooden frames and the interior fittings and finishings of these buildings and that their combustion caused the damage.

In studying the behavior of such large fires the effect of highly heated air in completing combustion cannot be ignored. Temperatures, corresponding very nearly to those obtained in regenerative furnaces, no doubt prevail, and no materials used for constructive purposes can withstand such high temperature, but the sources of danger can be guarded against by taking the exposure risk into consideration in the planning of fireproof buildings.

It is possible to lay out a floor plan with elevator and stairway shafts so enclosed that they will not act as vertical flues for a spread of flames, and it is also possible, by making the office partitions of non-combustible materials, to prevent the cross-drafts through the building, even though the outside of the building should be attacked. The neglect of these fireproof division walls and fire-bricks cost the owners of these high buildings much that could have been saved by their use, and in the future planning of such buildings this lesson should be borne in mind, as it is in intelligently designed "slow-burning" and wooden constructed building. Restricted areas: enclosed shafts and stairways, protected exposures, non-combustible window-frames and sash with wire-glass, automatic sprinklers and internal and external water protection, independent of the public service, would seem to be the remedies suggested to prevent occurrences of loss and waste similar to those of Baltimore.

F. Schumann.—No one having knowledge of the existing conditions, of the mingling together of fireproof, semi-fireproof, and combustible buildings in our larger cities, need be surprised at the recent conflagration in the city of Baltimore. Any of our larger cities is liable to a similar catastrophe at any time. There is no known building material or method of building that will resist the destructive effects of great heat, as is possible at this time in congested parts of our cities. Widespread conflagrations will occur now and again until the proportion of fire-resisting buildings becomes a maximum by the gradual elimination of those less resistant.

Notwithstanding the considerable knowledge we possess, as to the essentials to lessen destruction by fire, the fact remains that many of our so-called fireproof buildings are faulty in design and execution. Buildings supposedly fireproof are erected in the midst of older or combustible buildings, often stored with highly inflammable and combustible merchandise. No provision is made against the ingress of fire through openings, no separating fire-walls to confine the conflagration to a building, or within it, and when a fire breaks out under favorable conditions, such as a northwest wind charged with oxygen, frozen

water hydrants, a network of overhead electric and other wires, and a building stored with dry-goods, furniture, or paints and oils, the result can be foreseen.

I am of the opinion that architects and engineers can produce buildings having fire-resisting qualities, both from the exterior and interior, far superior to those now constructed, and that the great losses from conflagrations like the Baltimore fire can be positively avoided.

Assuming a modern fireproof building ornamental in design, the first consideration will be the avoidance of all combustible building material, the use of material that will resist heat most effectively, and the prevention of ingress or egress of fire through doors, windows, or other openings. In office buildings the furniture should be of metal, its use already anticipated by the existence of desks, file cases, and tables of very excellent design and workmanship. All door and window frames should be of metal and tile, and asphalt or concrete floors substituted for wood.

Apartment stores or buildings for the storage of merchandise, which necessarily contain much inflammable and combustible material, should have special provision, such as more massive outer walls, subdividing interior fire-walls with all openings protected by fireproof doors and shutters. The compartments resulting from the interior fire-walls should by all means be provided with ventilating shafts from the foundation up, for the escape of the expanded air and gases of combustion, in the event of a fire in a compartment. The counters and shelves in stores should be of metal having fireproof curtains or doors, and waste material, such as boxes, paper, etc., should have metal receptacles. Highly inflammable articles should be stored in separate compartments of the buildings and located with a view to isolation and ready control in the event of fire.

Well-burned clay-brick is the most efficient building material for resisting heat, and when used to protect metal construction great care is necessary in binding and anchoring it to the various members of the metal framework or floor beams. Expansion and deformation of walls and floors must also be provided for. Very efficient fireproof doors and shutters exist, and wire-glass in metal frames has proved a most excellent protection against the passage of fire.

Wise and active co-operation between the architect, engineer, insurance companies, and municipal building bureaus, aiming to isolate and gradually eliminate combustible buildings, and the rigid insistence for perfection in fireproofing, with the addition of the separate high-pressure water service, must result in the avoidance of great conflagrations in cities and the consequent enormous money losses.

Silas G. Comfort.—The subject of fireproof construction was treated quite extensively by Corydon T. Purdy in a paper read before the American Society of Civil Engineers, shortly after a destructive fire which occurred in Pittsburg in 1898. The circumstances of the fire were as follows: The Jenkins Building, occupied by the Jenkins Grocery Company, took fire in the night. Efforts were made to save the building, but the fire had gained such headway that the entire front wall fell into the street, thus carrying the fire across to the Horne Buildings, which were of fireproof construction. One of the Horne Buildings was occupied as a retail dry-goods store, and the other as an office building. The heat broke the glass in the windows, and set fire to everything adjacent to them. In a very short time the entire contents of the store building were on fire. On the upper floor scarcely a vestige of woodwork remained.

As to the suggestion brought out by Mr. Schumann, this was violated in the case of the Horne store building. It was six stories high without partitions, and with an opening in the center extending from the first floor to the sixth floor, surrounded on each floor by an iron balustrade. This opening made it very easy for the fire to spread from story to story. Where such openings, connecting one story to another, are necessary on account of light, they could be protected by asbestos covering made so as to roll up at the sides when not needed and then unrolled so as to come together in the center when needed. The separation of floors would appear to be very important in preventing the destruction of the contents of such a building. The external terra cotta and cut stone were badly cracked and scaled, while the face brick was but little injured.

The necessity for show windows is an objection to the use of metal shutters on the street front. It is the speaker's opinion, that, even with the best fireproof construction of large store buildings, one of the most important precautions is the installation of automatic sprinklers that will prevent or stop the spread of a fire in the contents of such buildings.

Washington Devereux.—Mr. Furber made a statement that a modern fireproof building took fire from an adjoining burning building. The building referred to had wooden window-sashes and plain glass, and was unsprinkled. A building not equipped with wired glass and hollow metal frames and outside sprinklers (dry pipe system) cannot be considered as slow-burning. There is nothing indestructible by heat. As a matter of course, all of our combustible buildings of to-day cannot be torn down and modern slow-burning buildings erected in their place. However, information that might be instructive to the public as to the possible causes of fires would probably do much to lessen the fire waste. For instance, spontaneous combustion, swinging gas brackets on wood or lath and plaster partitions, stationary gas brackets within eighteen inches of wood or other easily ignited material; the constant heat ascending first carbonizes and then ignites the substance, which may be more quickly brought about by excessive pressure on the supply pipes, blowing loose a gas tip, the flame often ascending a distance of ten or fifteen inches, rats and matches. Matches should be placed in a metal receptacle protected by an automatic cover. Steam-pipes on low-pressure systems in contact with woodwork have been the primary cause of fire, also hot-air pipes, gasoline stoves, oil stoves, and oil lamps are responsible for more fires than any other known cause. The use of benzine or gasoline for scouring purposes is most dangerous, and yet there are few households in this or any other city that do not keep a supply on hand, either as a moth-destroyer or to brighten up or cleanse furniture or needlework. Sawdust cuspidors, hot ashes placed in wood receptacles, lighted candles without metal candle-sticks, various polishing compounds whose principal ingredients are of an inflammable nature, sometimes cause fires.

James Christie.—Mr. Chairman: Almost all conflagrations in buildings give a strong impression of how much loss could be prevented if we could confine the flames to the building first attacked. In almost all cases the surrounding buildings are ignited by flames issuing through the windows and other apertures of the burning building, but usually not until the glass in the windows cracks and falls out, due to the burning away of the woodwork of the sash; even ordinary window-glass seems to withstand the heat very well, and though cracked to

maintain its place, and keep the flame within the building. The burning away of the sash, however, causes the whole sheet of glass to fall out, allowing sparks and flame to ignite surrounding buildings. This probably would occur as readily with wired glass, if it is set in wooden sash. To prevent this, the remedy would seem to be the use of metal sash and doors. There are cases on record in which ordinary wooden doors, covered with tin or sheet metal, like that shown by Dr. Leffmann on the screen, have withstood the effects of fire very well and restrained the spread of the flame until the total burning away of the wood caused the metal sheet to fall in.

We have to look at fireproofing construction from two standpoints: first, to prevent ignition of the building, if neighboring buildings are on fire; and, secondly, to prevent surrounding buildings from igniting from the building in which the fire occurs. For both ends it is necessary that the material closing the various apertures be able to withstand considerable degrees of temperature.

The Brown Hoisting and Conveying Company had a severe fire some years ago in a building with metal frame, brick walls, etc., but unfortunately it had a slate roof laid on planks with wooden purlins. A barrel of varnish was accidentally ignited, and the building destroyed in a very short time. Mr. Brown stated that he was satisfied that no building could be called fireproof unless all material used in it was incombustible, so the new building was constructed entirely of incombustible materials, sash, doors, and roof, with no wood.

It makes no difference what the building may be, or how refractory the material, if there is sufficient combustible matter present for the fire to obtain a footing, it will partially destroy the material, whatever it is. The records of the Baltimore fire show very well for our ordinary well-constructed fireproof buildings; that is, metal frames and reasonably good clay materials. Mr. Furber's allusion to this reminds one of the difference in the refractory qualities of different clays. Some fuse readily; for instance, those containing a large admixture of iron oxide, or alkalies. On the contrary, brick entirely silica or nearly all silica has a remarkable resistance. Concrete is coming largely into use, but unfortunately it has not yet proved itself, under similar conditions, a better fire resistant than clay tiling. Our best Portland cement concretes, if heated to 1000 degrees Fahr., show a material decrease in compressive strength, and when temperatures of fourteen or fifteen hundred degrees are reached lose 40 per cent. or 50 per cent. of their original compressive strength; consequently concretes cannot be classed as a material of very high fire-resistant qualities. The experiments of several independent observers confirm this considerable loss of strength. J. S. Dobie found that neat Portland cement briquettes heated to 1000 degrees Fahr. and allowed to cool in the air lost 10 per cent. in weight and 50 per cent. in tensile strength. If heated to higher temperatures and similarly cooled, the loss in weight was 10 per cent. and the loss in tensile strength 80 per cent. In both cases if plunged in water while hot, they fell to pieces. Johnson has shown that Portland and natural cement briquettes, both neat and half and half sand and cement, if heated to a red heat, lose from 60 per cent. to 90 per cent. of their original strength. These statements are confirmed by numerous experiments made at Pencoyd. The clay tiles in the other form of fireproof construction likewise suffer in many cases to an almost equal extent, by cracking, breaking off of edges, and in some cases by partial fusion. Both this and concrete fireproof

construction, though it may retain its form during the fire, if reached by water when still hot, will probably require at least partial reconstruction. Refractory qualities are not the only essentials for a fireproof material; it should also be a poor conductor of heat. Magnesite brick, though one of the most refractory materials that can be used in furnace design, conducts heat almost twice as readily as neat cement, and probably 50 per cent. better than the proportions of concrete ordinarily used. On this account, though not at present used as a fireproofing material, it is not perhaps as well suited for that purpose as a less refractory though poorer heat-conductnig material.

Concrete construction, on account of its low heat conductivity and the considerable thickness in which it is used, is well adapted to protect metal imbedded in it, even if subjected superficially to high temperatures for considerable periods.

The fact that actual cases of fire in buildings of concrete cement construction do not seem to indicate by results any such considerable loss of strength as is shown by the before-mentioned tests, is probably due to the test pieces used being of small bulk, and on that account being more readily heated to a uniformly high temperature throughout, while concrete beams or surfaces in a building are large in bulk and probably heated only on one or two sides. The facilities for radiation and the poor heat conductivity would thus retard the passage of heat to the interior, which would retain much of its original strength.

It would be a good plan for the architect to provide fire curtains of some reliable non-combustible material throughout the interior, so that in case of fire the burning area may be confined and isolated from other parts of the building. All authorities agree that fire can be more effectually prevented from spreading if apertures are kept closed, thus preventing bursts of sparks and flames. This can best be effected by the general use of metal sashes, fire-doors, wire-glass, etc., and by the firemen while fighting the flames leaving as few openings as possible in communication with the open air.

James S. Merritt.—I want to take exception to Mr. Christie's statement about concrete. I think the Horne Building at Pittsburg has been brought into the discussion this evening, and, if my recollection is correct, the committee of engineers appointed to investigate that fire were unanimous in stating that concrete had stood the fire much better than tile. Personally, I have seen tests by the Building Department of New York city where cinder concrete was subjected to a temperature of over 1700 degrees for three hours continuously, and was then flooded with water from below. The pressure on the hose was sixty pounds per square inch, and was kept up for five minutes. The floor tested was quite uninjured though of cinder concrete, so that I do not think that all concrete deserves the bad name that Mr. Christie gives it.

Edward S. Hutchinson.—I would like to ask Dr. Leffmann what temperature the wire-glass was subjected to in the experiment, the slides from which he showed a few moments ago.

Mr. McDevitt.—Mr. Chairman, in answer to that, the Baltimore Underwriters made tests with buildings constructed just the same as Dr. Leffmann showed. The first test was a cord of wood set under a window-sill. The temperature rose to 1900 degrees in half an hour; the next test was the same quantity of wood on the inside of the building; the temperature rose to about 1900 degrees, and it was a very severe test—not quite as bad as the fire in Baltimore. Both

the frame and the glass stood pretty well. One thing we observed, the heat penetrated the wire glass the same as with ordinary window-glass. We made tests with a possibility of igniting inflammable material on the inside, which we found would be the case. This transmission of external heat has been lessened by the use of a double case frame with, say, two sashes and a space between. Speaking of metal frames, in the Baltimore ruins there is a bank building, about the size of our Franklin Institute, with burned buildings all around it. We wondered how it escaped, and found that the window frames and sash were made of steel. The glass was all gone, but the windows were protected on the inside by steel shutters. It was a brick building trimmed with dark-colored stone. The roof was tile, on iron beams. Some of the walls fell on the roof, but, except for that, the building was saved from the fire. Here is an example of how easily these skyscrapers can be protected with steel shutters on the inside of the building. They would not look objectionable and could be closed from the inside of the building. The paint was burned off the shutters, the glass of course was gone, but the steel sash and frames were good. The rear of one of the buildings shown, had wired glass with metal frames. It stood a very severe fire, but is in pretty good shape. Some of the windows were broken, but I found on looking inside that there was nothing there to take fire—it was all metal construction. There is no glass of any kind that could stand the temperature of that conflagration. You could not expect it. The building of which I speak still stands. The inside steel shutters are still in place, nothing but the paint came off. These inside shutters apparently afford as much protection as outside shutters.

Walter Loring Webb.—I want to suggest, by way of explanation, the cause of the discrepancy between the statement of Mr. Merritt and Mr. Christie. Mr. Merritt referred to cinder concrete. Is it not possible that the cinder concrete, the matrix of which is composed of fine particles which have already been subjected to very severe heat, will not be so affected by fire or even by the severe treatment of throwing cold water on it, when stone concrete might go to pieces? Of course, the stone concrete is stronger structurally and better in that respect, but I have an idea that the cinder will stand heat better.

Mr. Furber.—The statement that cement is a fireproof material can hardly be upheld by chemical investigation. When it is realized that about 25 per cent. of water is crystallized in its composition, it is obvious that intense heat will drive this water off and thus disintegrate the mass. I have made a number of experiments on pieces of porous hollow clay tile, heating them to redness and then plunging them into water, and in no instance did the fire-clay tile suffer apparent injury. I have also made a number of similar experiments with cement briquettes of varying composition, and in no instance did the briquettes fail to disintegrate, either wholly or partly, for the chemical reasons previously mentioned.

Cement or concrete is a slow conductor of heat, and for this reason may make a better apparent showing than might be expected, but the continued application of heat must disintegrate the whole mass.

Henry H. Quimby.—Mr. McDevitt referred very briefly to an occurrence that he declared was really responsible for the spread of the fire beyond the Hurst Building. The daily papers referred to it somewhat vaguely, probably

because it was not very well understood. There must be some facts of scientific interest connected with it. It was the explosion of smoke in the building. I have had occasion to make tests of the ignitibility of mixtures of gas and air. Gas will not ignite without a sufficient admixture of oxygen. Our illuminating gas here requires to ignite it at all as much atmospheric air as three times its own volume, and then it ignites slowly—that is, with very little explosive effect. Its maximum explosive quality is reached with a little over six times its own volume, and it will not ignite if the percentage of gas in the mixture is less than 7½ or 8, depending on the composition of the gas. Probably in the Hurst Building a hydrocarbon smoke was generated by the fire that started there, or a large volume of illuminating gas escaped from broken pipes and did not ignite until a sufficient percentage of air became mixed with it. I think it probable that the destruction of the city of St. Pierre on the island of Martinique was caused by gas. I believe (though I have not seen the theory advanced) that the volcano had emitted a large volume of gas which did not take fire until it had spread far—probably covered the city—and by that time becoming mixed with sufficient atmospheric air, ignited with explosive suddenness and intense heat. It seems to me that this is the only theory that will account for the phenomenon of the disaster. I think that the admixture of gas and air accounts for the explosions in conduits and manholes which have occurred recently. If we can find some means to fight a fire while we prevent the introduction of air into the building that is on fire, we will lessen the danger of an explosion.

Mr. McDevitt.—In reference to that subject, the gentleman is right. These explosions do not occur until the air is admitted. Admit the proportions of air, combined with the gas, and that is the time you get the explosion. Then during the fire we see another collection of smoke which is very thick and in excess of the proper proportion of oxygen, then we do not get the explosion. Generally, just as soon as the firemen open the door, which they have to do, then the explosions occur, as there is a sufficient proportion of oxygen allowed to enter the building. I suppose you are all aware that smoke is escaped combustible matter. It vaporizes, gets cooled as it rises from the heat, and condenses into a cloud which we call smoke. Just as soon as the oxygen is spread out it then forms a highly explosive mixture. In every case in which explosions occur, it is at the earliest stage of the fire, just by opening the door and allowing sufficient oxygen to ascend and mix with smoke. Our firemen here generally try to get on the roof, break it in and ventilate it. From tests, I find that the slightest saturation of moisture will kill the explosive effect. If sprinklers were in the building and were opened, you would not be apt to get an explosion.

Mr. Schumann.—In connection with the remarks of Mr. McDevitt, it seems to me that ventilating shafts or ducts, leading from the subdivisions in a store or a building filled with combustibles, are an essential for the escape of the gases of combustion. I believe destruction is often due to sudden expansion in explosion of gases generated by a fire and confined by reason of a lack of outlets.

Mr. Hutchinson.—Referring to the effect of smoke in adding to the force of an explosion, I had occasion, some years ago, to investigate the causes of an explosion in the coal mines of the Southwest Virginia Improvement Company, in the Pocahontas region of West Virginia, and the result clearly showed that the fine particles of dust floating in the air, as well as the dust accumulated

on the floor of the mine, materially increased this force. The carbonization extended several hundred feet from the initial point. While the two instances are not alike, yet it is reasonable to infer that the very finely subdivided carbon of smoke is much more readily ignited than mine-dust.

The President.—The fire in Baltimore seems to have been an exceptionally hot one, as I understand that there was absolutely no unconsumed combustible material left in the debris. It seems as though most of the buildings had been heated to a very high temperature before combustion began; after it began it was naturally very rapid.

There was an incident of interest, in connection with some papers in the inside of a fireproof safe. This safe contained, closely packed in the pigeon-holes, the books of a company, while in the vacant space in front there had been placed a lot of loose papers which were of comparatively little value, and had been hastily put in the safe before it was closed. During the fire the safe had become red-hot on the outside. After the safe had been cooled with water it was opened, and it was found that the things which had been closely packed in the pigeon-holes were completely consumed, while the loose papers in the open space in the front part of the safe were practically uninjured.

In connection with the subject of the source of fires, it might be of interest to call attention to the fact here, that a number of fires have been started in cleansing establishments by electric sparks generated by the friction of the woolen materials and the benzine or gasoline in which they were being washed. These electric sparks are generated in the same way as when the fur of a cat is stroked by a hand. It seems that when these goods are raised out of the tanks the friction of the liquid against the fabric generates these sparks, and when this occurs in the open air above the tanks, ignition naturally follows.

Harrison Souder.—There is one point that has not been touched upon in this discussion, and that is the value to any city, of occasional boulevards or parkways, say 150 feet wide or more, running through and around the city; providing thus not only handsome driveways, but valuable fire stops. These would be of great assistance in confining fires within given districts and give better opportunities for fighting them. Baltimore realizes this, and is planning to widen the streets in the burned district. It would seem that the Baltimore fire would supply a strong argument in favor of the boulevards and parkways which it is proposed to establish here in Philadelphia.

# NEW STEAM TURBINE DEVELOPMENTS.

W. L. R. EMMET.

*Read March 19, 1904.*

SINCE previous papers and publications have described the earlier work on the Curtis turbine, and have given results accomplished by the machines first developed, it is undesirable to go into all these details again, and therefore the scope of this paper is principally confined to the work and experiences of the past year.

A paper read by the writer before the American Philosophical Society in this city last April gave the results obtained from the first commercial Curtis turbine built at Schenectady, and described designs of other machines then in process of development. This paper also made certain predictions concerning the possibility of the type, and claims as to its superiority over other engines and turbines which were then known to the world. These claims and assertions called forth some vigorous protests from Europe, where much active turbine work was then in progress. The results of tests, given in the paper above mentioned, were at the time of their publication the best record of a turbine performance which had been given to the public in America, and this fact, in connection with the complete practical success of the unit in question, justified all the statements that were then made concerning it and the type which it represented. Shortly after the publication of this paper, test records were published which showed very good results with large European turbines of the Parsons type, and which seemed to justify the protests which had been made against our rather positive claims of superiority.

All the statements in my paper of April, 1903, referred to designs which were decided upon before the first practical operating experience with the commercial Curtis turbines had been obtained, but the commercial results accomplished since with the machines first put out, alone justify the claims made. After the first commercial machines had been experimented with, and when the theories and possibilities relating to their action had been studied, we decided to make some radical changes of type based upon new theories and experiments. The first machines of this new type have just been completed and put into operation. These newer machines show very marked

improvements over the first machines designed, and seem to further justify our most sanguine predictions. The first vertical shaft turbines built by the General Electric Co. were of 500 kw, 1500 kw, and 5000 kw capacities; and in the matter of arrangement of stages, nozzles, and buckets, were very similar to the horizontal shaft machines originally built. In these respects they were based upon the ideas embodied in Mr. Curtis' first conceptions. The first of these vertical shaft machines was put into commercial operation less than a year ago, and since then about fifty have been shipped and at least twenty have been put into service. In operating all these machines there has been ample opportunity to test the practicability and value of the novel features which they embody.

The paper read before the Philosophical Society was the first publication concerning turbines of this vertical type, and it called forth many comments concerning the possible difficulties of designs. These were the first machines of such great weight to be operated on vertical shafts at such high speeds. Vertical shafts had been used before for many purposes, but their use had been under conditions where the problem of support and lubrication was very different. The method of governing and controlling valves was also new, and the method of packing the shaft, where it passes out of the turbine casing, was different from anything which had previously been used. The generators also were of new type, quite different from anything which had previously been produced. The designing and starting of these machines therefore presented a very complicated problem, and trouble with some details was reasonably to be expected. Experience has shown that, in all essentials, these designs are practical and desirable. The difficulties encountered have been in relatively unimportant details and from unexpected causes.

The first machine of this type to be put into service was of 500 kw capacity and was installed at Newport, R. I. Since its installation two other similar machines have been put into the same station. The first of these machines has been in service since July, 1903, and the other two have been in service for several months. The service of this station has been carried by these turbines without interruption, and the results accomplished by them have been very satisfactory. Several troubles were discovered soon after starting, and much experimenting has been done with the owner's consent; this plant being, by agreement, selected for this particular purpose. These experiments have led to the circulation of reports of trouble, but in reality

have not arisen from any trouble of very serious character. The first serious trouble encountered was with the balance of the generator, which had not been very carefully considered before the installation was made. Imperfection of balance gave trouble with the bearings,

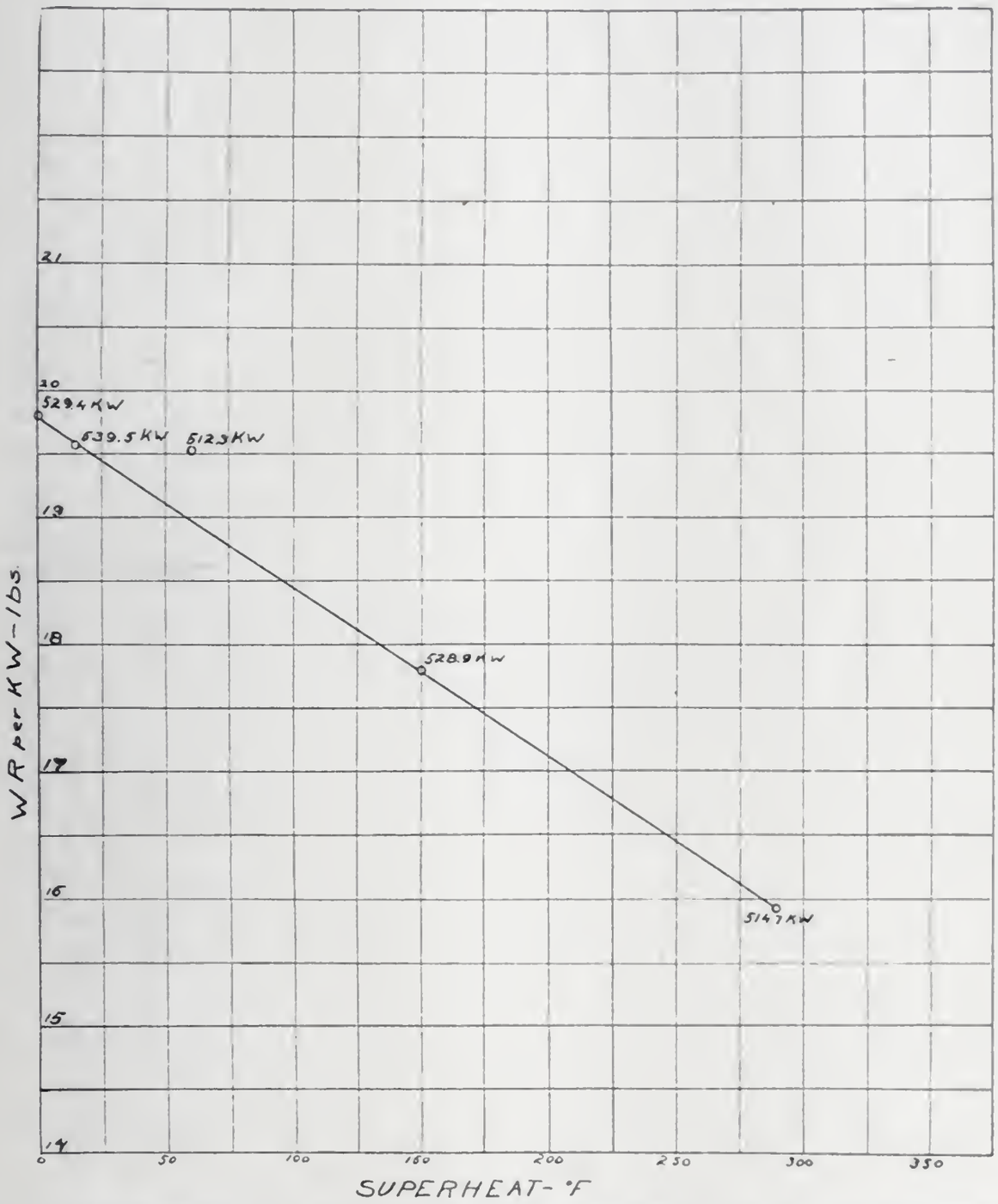



FIG. 1.—FIVE HUNDRED KW CURTIS TURBINE AT NEWPORT, R. I. CURVE SHOWING EFFECT OF SUPERHEAT ON STEAM CONSUMPTION (WATER RATE PER KW HOUR).

which trouble was overcome when the balance was improved by the attachment of suitable weights. The original construction of the step-bearing made possible a certain degree of instability of its action under certain conditions, and changes of design were adopted, very

soon after the starting of this machine, which have entirely overcome this trouble. The valves as originally designed for this machine were imperfect in certain respects and had to be redesigned, with certain

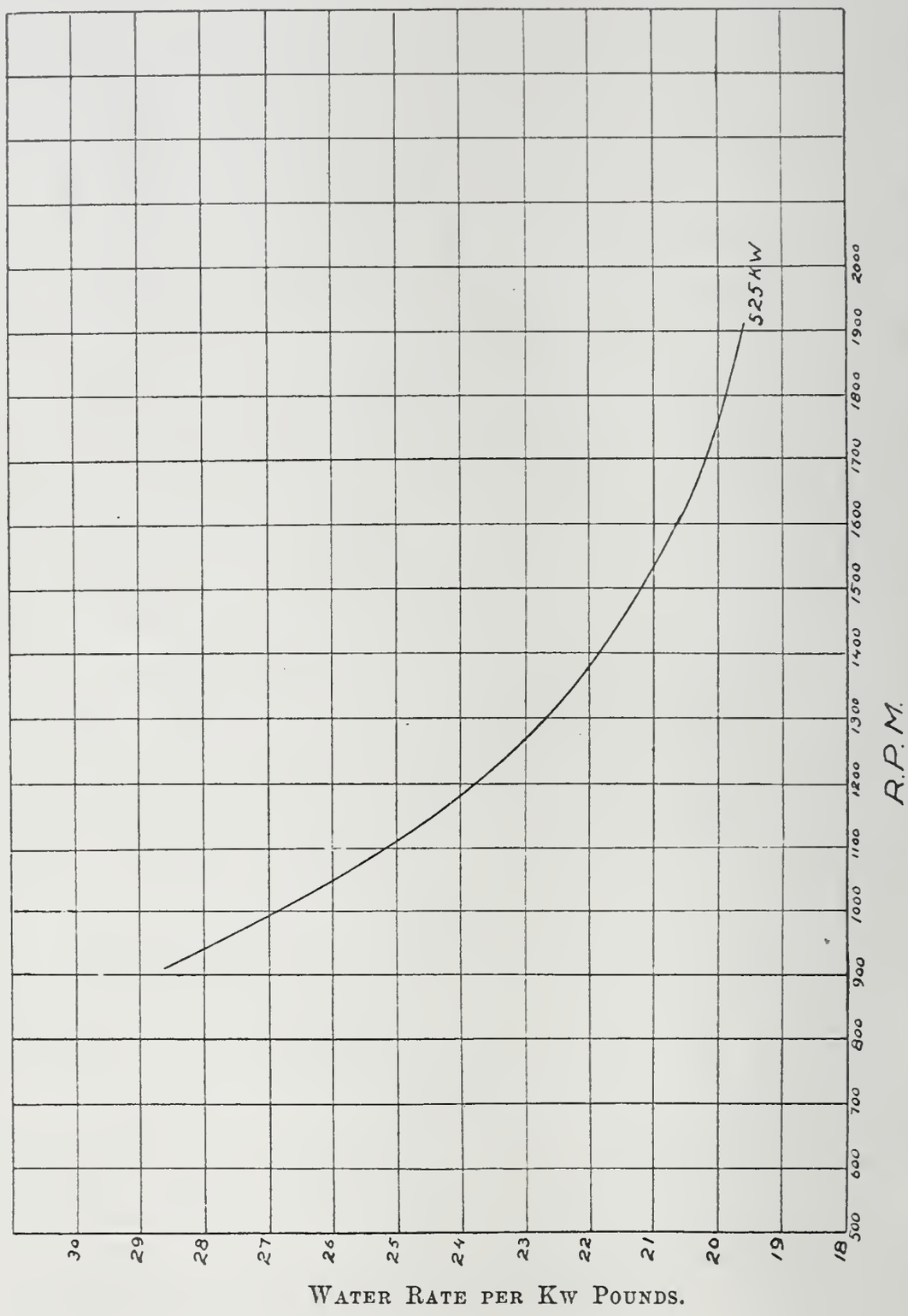



Fig. 2.—Five Hundred Kw Curtis Turbine at Newport, R. I. Curve Showing Effect of Speed on Steam Consumption (Water Rate per Kw Hour).

changes of proportions in parts, but without any change in the general character or principle of action. For a long time past there has been no trouble in connection with the Newport installation, and there are now about fifteen similar machines operating without trouble of

any kind. There are still improvements contemplated in connection with these machines with a view to reducing the labor of their attendance and diminishing the possibility of interruptions. It has

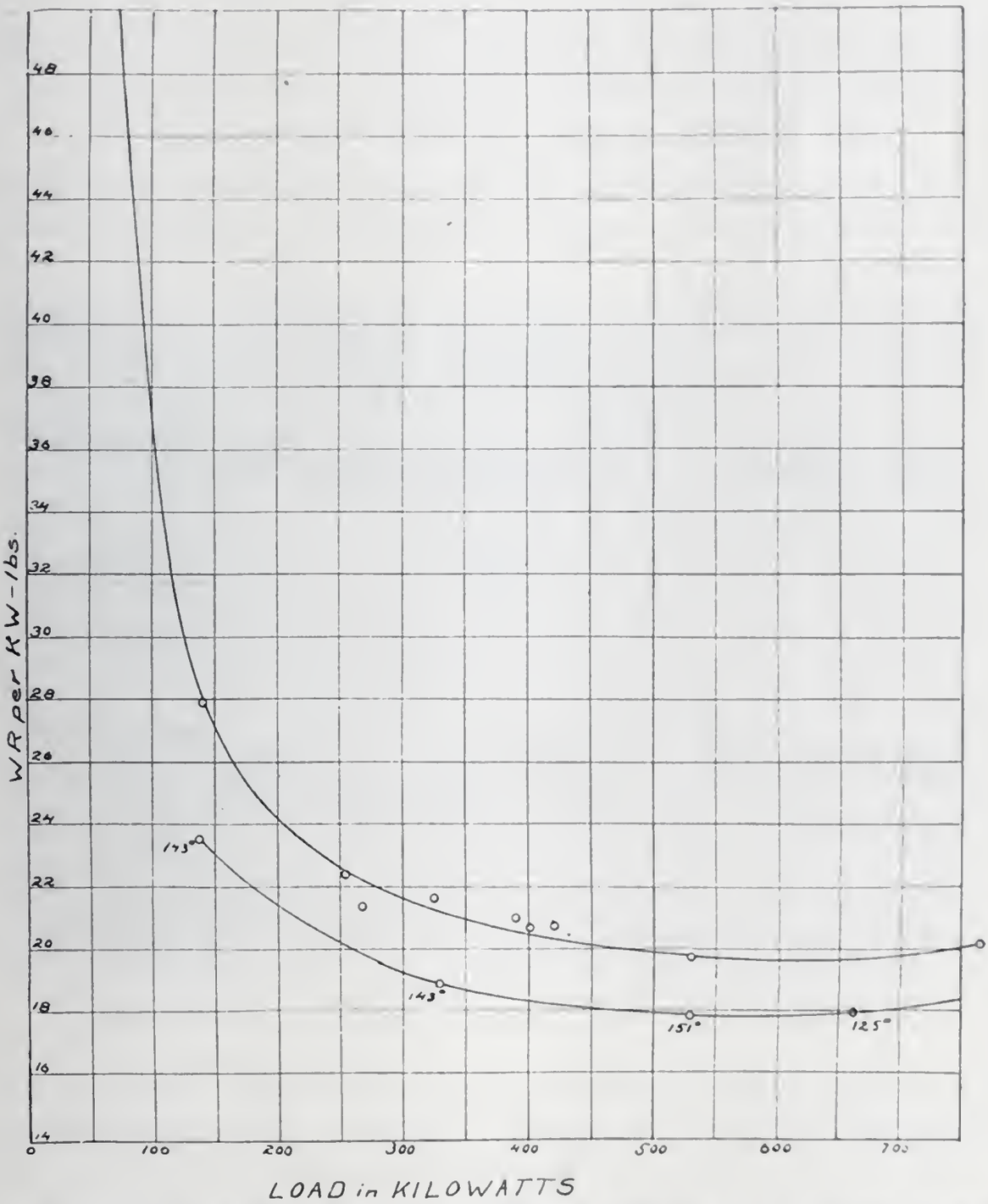



FIG. 3.—FIVE HUNDRED KW CURTIS TURBINE AT NEWPORT, R. I. CURVES SHOWING STEAM CONSUMPTION (WATER RATE PER KW HOUR) AT DIFFERENT LOADS, WITH AND WITHOUT SUPERHEAT. INITIAL PRESSURE 145 GAUGE.

been proved, however, that their original designs, almost without change, were practicable and advantageous for commercial service. A short time ago tests were conducted on these machines by Mr. G. H.

Barrus on behalf of the purchasers, with a view to ascertaining whether they had met the guarantees of the contract. The tests showed that the contract guarantees had been met and also showed many of the practical advantages of machines of this type.

### The Following Report Gives the Results of Tests Made Upon 500 Kw Turbine Set Manufactured by the General Electric Company and Installed at Newport, R. I.

This set is equipped with a 60 cycle 2300 volts generator and is used for a supply of current for lighting and railway purposes; the railway

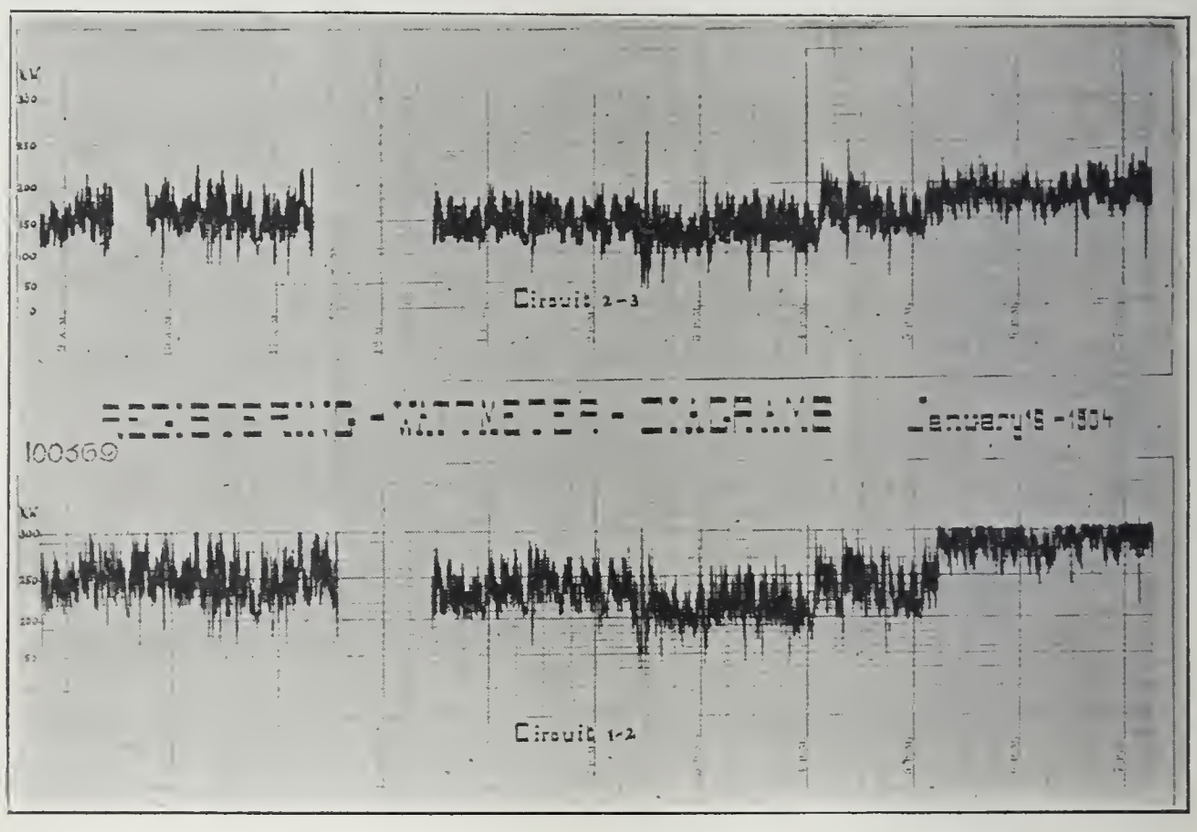



Fig. 4.—Commercial Run—500 Kw Turbine at Newport, R. I.

work being the most important part of the load. The tests were conducted by George H. Barrus, of Boston, who represented the owners, the Massachusetts Electric Co., and Mr. Richard H. Rice, recently of Rice & Sargent, and A. R. Dodge, who represented the General Electric Co. Tests were made and water rates measured with various conditions of fixed load with and without superheat, as shown by the curves (Figs. 1, 2, and 3). Tests were also made with such commercial loads as are daily experienced in this plant, and the steam consumption per kilowatt hour under working conditions was ascertained by the most careful determinations of the total

water condensed, and the load as measured by many instruments and as recorded by carefully checked recording wattmeters.

Attention is specially called to the records of operation under commercial load, since they illustrate the great practical advantage afforded by apparatus of this kind. The character of the load during these tests is shown by diagrams Figs. 4, 5, and 6, which indicate incessant fluctuations, with an average sudden variation of about 100 kw, and with an average load of only 253 kw in one case and 421 in another. In the former case the average steam consumption per kilowatt hour was only 22.38 pounds. It can be positively asserted that the best steam engines now used for such purposes, in this country,

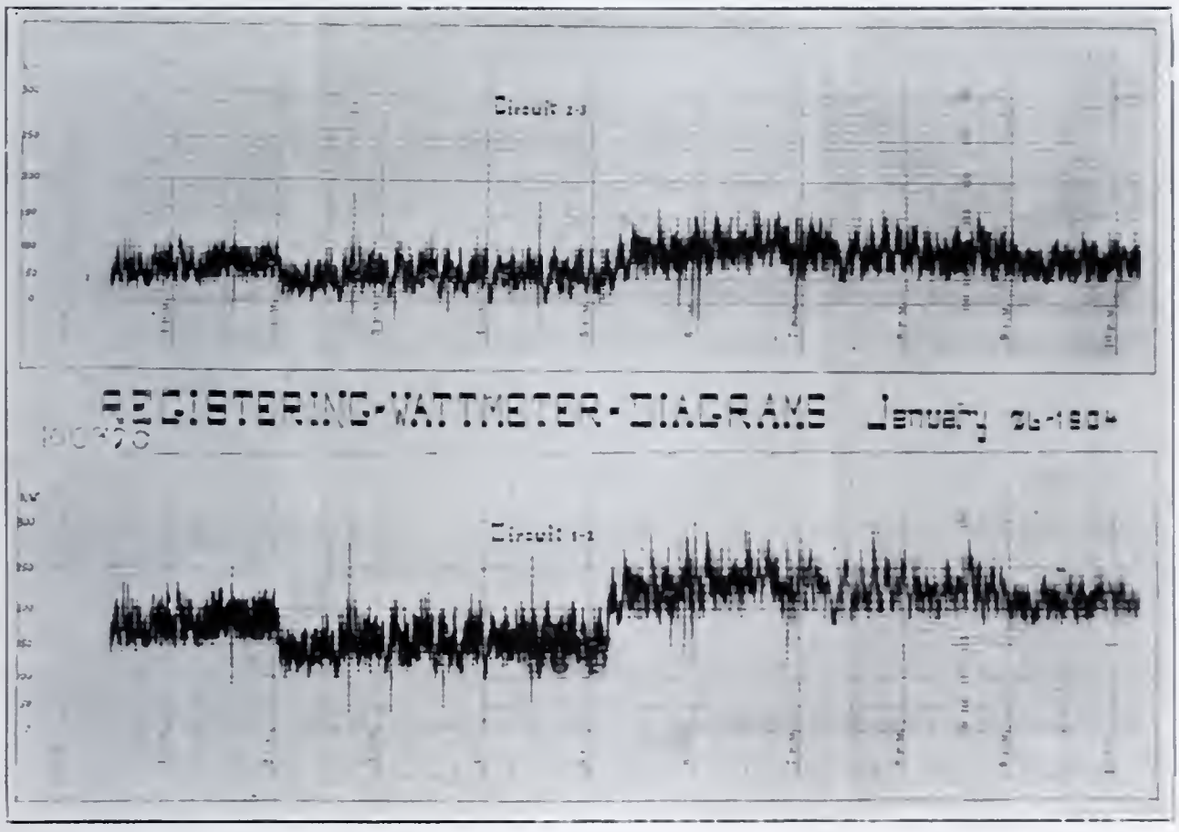



Fig. 5.—Commercial Run—500 Kw Curtis Turbine at Newport, R. I.

would consume at least 28 pounds of steam per kilowatt hour under such load conditions, and in most cases the consumption would be considerably larger. The consumption of 20.73 pounds per kilowatt hour with an average of 421 kw of such variable load, is also a very fine performance.

In considering these results, it should also be borne in mind that the plant which gives these results possesses many other practical advantages which conduce to economy. All the condensed water in this plant, since it originally started, has been returned directly to

the boilers, and the boilers are, consequently, at the present time in a perfectly clean condition, although the natural water-supply of Newport is bad. During all this time no oil has passed into the boilers nor been wasted; it is simply circulated and used over and over again. The absence of air leakage in the turbine, and the absence of air in the feed water, greatly simplify the maintenance of a good vacuum,

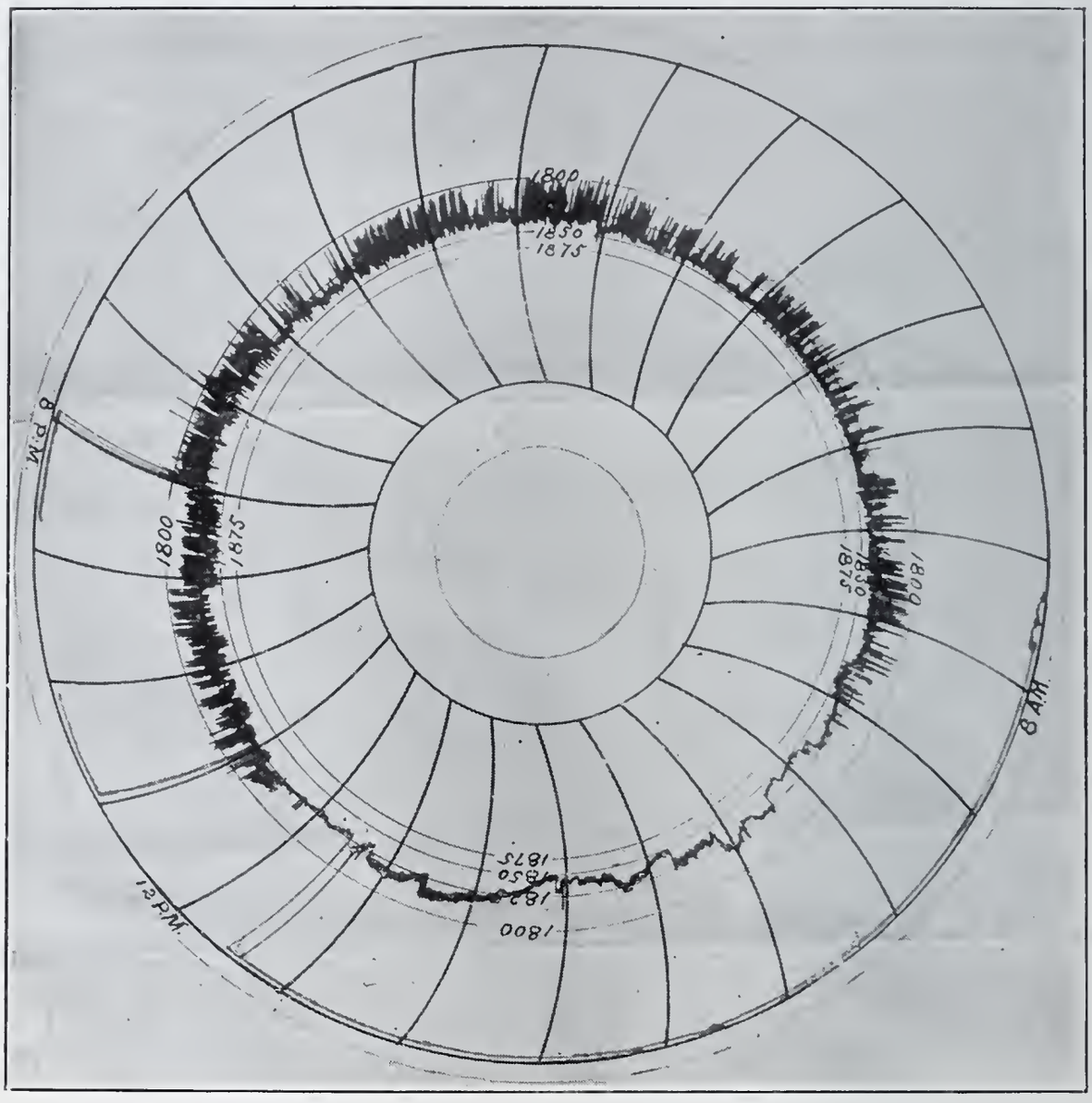



Fig. 6.—Recording Tachometer Chart, Showing Speed Regulation with Commercial Loads. Five Hundred Kw Turbine at Newport, R. I.

which, of course, contributes to these excellent practical results. The whole arrangement of this plant is compact, simple, and easy of maintenance, and the results are representative of those which can be obtained anywhere from such apparatus where the water for condensation is available.

These results were obtained from the first of our commercial turbines,

and we expect in future work to greatly exceed the degree of economy here shown. Since the design of this machine our turbines have been greatly changed and improved, and these results should not be considered as representative of the type. It is questionable, however, whether practical results under service conditions as good as these can be shown by other existing engines or turbines, although less water consumption may be shown under certain conditions of load.

SUMMARY OF COMMERCIAL RUNS OF JANUARY 15TH AND 26TH, 1904.

| | January 15, 1904 | January 26, 1904. |
|---|---|---|
| Duration, | 12 hours | 15 hours |
| Total coal (wet), | 13,517 pounds | 10,205 pounds |
| Moisture in coal, | 3.1 per cent. | 5.5 per cent. |
| Water evaporated, | 127,267 pounds | 104,026 pounds |
| Drip withdrawn from steam pipe per hour, | ——— | 46 pounds |
| Moisture by calorimeter, | 3.05 per cent. | 2.1 per cent. |
| Total steam to turbine, | 108,100 pounds | 86,833 pounds |
| Steam per hour to turbine, | 9008.5 pounds | 5769 pounds |
| Dry steam per hour to turbine, | 8733.8 pounds | 5667 pounds |
| Load by polyphase meter, | 406.4 kw. | 234.7 kw. |
| Load on auxiliaries (average), | 14.9 kw. | 18.5 kw. |
| Total load (average), | 421.3 kw. | 253.2 kw. |
| Dry steam per kw hour, | 20.73 pounds | 22.38 pounds |
| Dry coal per kw hour, | 2.67 pounds | 2.54 pounds |

In October, 1903, the first 5000 kw turbine was installed in the new plant of the Chicago Edison Company. This machine was put into commercial service soon after its installation, and since that time two others have been installed. The first machine has been in commercial service daily since its original starting, and the second machine has been in service for several months past. Neither of them has been subject to any interruptions of service through its own defects, and for some time past they have both operated almost continuously. They have, on some occasions, been kept under load for five days without stopping. In many cases they have operated with extreme overloads and have regularly been depended upon throughout the winter. Several unforeseen troubles have been experienced with these machines also. The valves, as originally designed, have been subject to the same difficulties experienced at Newport, and have been replaced by valves of such improved construction as could be applied without loss of time or interruption of service. This trouble with valves has, however, caused no stoppages, since the principle of

governing is such that each valve operates independently, so that the failure of one simply serves to throw the work on to the next in order.

There have also been in Chicago certain unexpected movements of wheels, through variations of temperature, which have made necessary certain adjustments which were not originally intended. The fact that machines have been required for daily service has made it impossible to correct the cause of these difficulties and has occasioned a little inconvenience in handling them. No trouble has arisen in connection with these, or other machines, which is not readily curable and which cannot be avoided in all future machines, and none of the troubles has been of sufficient magnitude to interrupt the continuity of service or appreciably impair the efficiency of action.

The machines in Chicago operate with wonderful steadiness and freedom from vibration under all conditions of load. The generators are cool and have given no trouble whatever. The electrical regulation is good and the speed control has always been perfect, in spite of the difficulties with valves above mentioned. The machines have repeatedly been subjected to sudden accessions of heavy load, in cases of accidents with other apparatus, and have repeatedly been called upon to operate non-condensing without interruption of service, through some failure of the condensing facilities. In all such cases they have successfully performed the duty for which they were designed. The step-bearings have never given any trouble from the time the plant was started. Some changes are still contemplated in connection with these machines, and they will be applied when any of the machines can be spared from regular service. These changes are not of an important character and it is expected that they will overcome the small inconveniences which remain. No official tests of the Chicago units have ever been made, and no accurate knowledge concerning their steam consumption is possessed. Tests were begun at one time, but a large and variable leakage in the condenser made it impossible to weigh water, and testing was postponed on account of the late season, which made it necessary to keep the machine in commercial service. The facilities for shipment limit the diameter of a 5000 kw machine of the Chicago type, and it is therefore designed for a lower peripheral velocity than other machines of the kind. It was guaranteed to give about the same steam economy as the machine at Newport, and it is probable that it gives a very similar result.

As has been said the development of our ideas led us to adopt new principles of turbine designs before the machines above mentioned were put into service, and it is only very recently that the first machine of this new type has been run and tested. These new condensing turbines, which have been designed within the past year, are still of the vertical shaft type but have four stages, while the machines above mentioned have only two. In each of these four stages there is a cast-steel wheel carrying at its outer edge two rows of buckets; the stages being separated by diaphragms which form separate compartments, and which are so shaped as to bear the pressure of steam to which they are subjected. In these diaphragms, or attached to them, are sets of nozzles which deliver the steam to the wheel of the succeeding stage, the number and size of these nozzles, and the portion of the circle which they cover, increasing from stage to stage as the steam expands. The wheels of these machines are of extremely simple construction and the attachment of buckets is simple and strong. They are operated with ample clearances and no adjustment whatever is required in their operation under any conditions. The machines can be started immediately without preliminary heating, and require no adjustments with changes of temperature, load or vacuum. These new machines are governed solely by the original admission of steam; the number of first stage nozzles in flow being controlled by the governor, and always kept proportional to the load. The stationary buckets in these machines project from heavy strips of metal fitted in slots and firmly held to the stationary part by heavy bolts from the outside. The construction is such that the injury through accidental interference between the moving and stationary parts is very small, no distortion or warping being possible. The construction of the machine, however, and the ample clearance, make it easy to avoid such touching altogether, even where machines are started for the first time.

We have recently tested a 2000 kw machine of our new four-stage type under the conditions of vacuum and superheat afforded by our Schenectady power station. These tests have not yet been carried far enough to fully analyze the possibilities of this machine with the best adjustment of shell pressures and all other conditions. The tests have, however, shown remarkably fine steam economy, and it is probable that still better results will be produced within a short time. The results and conditions of some of these tests are as follows:

| | February. | | March. | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 23d. | 25th. | 11th. | | | 12th. | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Load in kilowatts, | 1750 | 2400 | 1740 | 2210 | 2760 | 637 | 1000 | 2000 |
| Revolutions per minute, | 760 | 760 | 750 | 750 | 750 | 750 | 750 | 750 |
| Gauge pressure, | 140.5 | 156.5 | 155 | 160 | 160 | 150 | 160 | 160 |
| Superheat, F., | 200 | 239 | 202 | 212 | 192 | 215 | 242 | 242 |
| Inches of vacuum, | 28.5 | 28.5 | 28.73 | 28.50 | 28.35 | 28.2 | 28.9 | 28 78 |
| Pounds of water per kilowatt hour, | 14.2 | 13.5 | 15.30 | 15.20 | 16.20 | 20.1 | 16.30 | 15.30 |

After the first two tests here reported, a change in the arrangement of the machine was made, and this change produced an unforeseen condition, which we think was very disadvantageous to the machine. All the tests given were made with the best facilities for long periods with perfectly fixed conditions, and we have every reason to believe that all are nearly correct. The tests made under the second condition were witnessed by many prominent engineers, and all the conditions were accurately verified. It seems to be quite certain that the best arrangement of the machine will give a result better than any that has been obtained. While these tests do not give a complete and conclusive record of the possibilities of this machine under all conditions, they certainly demonstrate that its steam economy is superior to that of most engines or turbines which are available for similar purposes.

Satisfactory tests, without superheat, have not yet been made upon this machine. The indications of such tests as have been made are that the improvement with superheat is very large, and that in this respect the functioning of the machine is very similar to that of the Parsons turbines, which show more benefit from superheat than the earlier turbines of the Curtis type. The use of high degrees of superheat has been considered commercially desirable in connection with the Parsons turbines, and the indications are that the same reasoning applies to machines of this type.

These machines are designed to operate with superheat, without any mechanical difficulty, and it is probable that future steam plants designed for the use of such apparatus will use high steam temperatures. In the course of tests with experimental turbines Mr. A. R. Dodge, of Schenectady, has observed certain conditions which indicate serious errors in the ideas previously accepted concerning the specific heat

of superheated steam, and these observations have led us to make investigations of this matter. By delivering superheated steam to a turbine fitted with a water brake we can, at will, vary the amount of work extracted from the steam, until the exhaust is brought to a saturated condition. If we know accurately the temperature and weight of exhaust steam, and the temperature and pressure of the steam admitted, and have an exact measure of the work extracted from the steam, and of the heat radiated, we have in our possession all data necessary to calculate the total heat of steam admitted. This method of test is subject to certain difficulties and inaccuracies, but has the advantage that it can be carried on on a considerable scale with large flows and steadily maintained conditions. We have made such tests with different degrees of superheat, and have checked approximately some of our results by other methods of investigation. The result of these tests indicates that the specific heat of superheated steam under the conditions ordinarily used is much greater than has generally been supposed. The idea generally accepted, until quite recently, has been that the specific heat of superheated steam under all conditions was 0.48. Our investigations indicate the following figures:

VALUES OF Cp AT 155 POUNDS ABSOLUTE.

(Cp being the average of specific heat up to these temperatures; not the heat required for a rise of 1° at these temperatures.)

| Superheat. | Cp. |
|---|---|
| 0° F. | 0.52 |
| 100° F. | 0.65 |
| 150° F. | 0.7 |
| 200° F. | 0.74 |
| 250° F. | 0.77 |

It is probable that our investigations on this subject will be carried further, and that Mr. Dodge will publish fuller and more accurate figures. Since this work was done, very similar figures have been arrived at independently and by different methods in England and in Germany.

The design of steam turbines is susceptible of many variations in mechanical arrangement and steam action. It is probable, however, that the four-stage machine here described will hold its own against all competing engines for some time to come, and that it will be extensively used.

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The President then announced the paper open for discussion, and

in reply to questions from members and visitors Mr. Emmet explained as follows:

This type of turbine is adapted to operation between any pressure limits, and the work obtained will generally vary in approximate proportion to the variable energy in the steam.

The wear of buckets, as determined by experience with existing machines and by experiment, is so small as to indicate inappreciable expense in maintenance. The appreciable wear is confined to parts which are in continuous contact with steam having a high density and high velocity, and these parts are small, inexpensive, and easily replaced. The first set of stationary buckets is subject to more wear than any other part. In a 500 kw machine this part should wear at least two years and should not cost more than $25.

All of these turbines have been designed for electrical purposes and for operation at a fixed speed; the design being made with a view to accomplishing the highest attainable economy at this speed. The machines will, however, operate at other speeds higher or lower, and will give a fairly good economy through a considerable range of speed. I cannot, from memory, give specific data on this subject. Such machines give a large torque at low speeds, but there is, of course, a very rapid reduction of efficiency as the speed is reduced. The normal speeds of some of the machines which I have mentioned are as follows: 5000 kw, 500 r.p.m.; 2000 kw, 750 r.p.m.; 1500 kw, 900 r.p.m.; 500 kw, 1800 r.p.m. All of these speeds are fixed by the frequency of the alternators which they drive.

All of the machines, which have been described, are designed for operation with condensers. They all are suitable for use non-condensing, and it may be roughly estimated that their steam consumption non-condensing would be about twice as great as it would be with a good vacuum. It is hoped that better non-condensing results can be obtained with designs made particularly for that purpose.

When these machines are operated with superheat, the bearings are in no way affected by the high temperature; the bearings being entirely external to the turbine.

The relative economy of one of these turbines and a Corliss engine may be judged by the steam consumption figures which have been given. Much of the advantage of the turbine in this respect arises from the high degree of expansion which can be provided for in its design. Under conditions which are ordinarily practicable, I think that the turbines, even in their present state of development, are very decidedly superior to Corliss engines.

There is no appreciable change in speed of turbine when the machine passes from a condensing to a non-condensing condition. To operate with the same load non-condensing, it must open more admission valves; consequently the range of speed would be slightly greater. As our machines have generally been built, the maximum variation of speed non-condensing would not exceed 3 per cent.

The pressure required in step-bearing of 5000 kw machine is about 1000 pounds per square inch, and that in 500 kw machine is about 200 pounds per square inch.

The clearance between moving and stationary parts in the four-stage machine, which has been described, is about 0.05 of an inch. A less clearance would be practicable, but would be of very little advantage.

The effect of wear upon the step-bearing is to gradually lower the revolving part. In the 500 kw machines with which we have experimented, the lowering, after the lubricant had been stopped, went on at the rate of about 0.01 of an inch per minute. In no case has any damage been done through the failure of the step-bearing except the wear on the blocks themselves, which involves inappreciable expense. As a rule, it is not necessary even to re-surface the step-bearing blocks after a stoppage has occurred. They tend to wear to a proper engagement, and if they do not, they can generally be made to do so by successive short interruptions of the oil pressure. In properly arranged installations, troubles of this kind can easily be avoided, and this should, of course, be done if possible. Weighted accumulators, as a reserve on the pumping system, are very desirable in this connection.

The effect of rubbing, between the moving and stationary parts of these machines, causes surfaces to wear away gradually, but does not cause the rapid injury which might be expected. In many cases, through improper arrangements or inaccuracy of work, we have had serious and repeated rubbing, but in no case has this put a machine out of service or caused any serious injury to it.

The smallest machine which we have built is of $1\frac{1}{4}$ kw capacity, designed to run an electric headlight on a locomotive. Its speed is 5000 revolutions per minute.

The packing around the shaft, where it passes from one compartment into the next, in our existing turbines, simply consists of a loose sleeve which gives a considerable clearance around the shaft and is free to center itself. The pressure tends to hold this sleeve in any

position to which the shaft may force it. Since the sleeves are inaccessible, considerable clearance is used, that there will be no risk of cutting. There is, of course, a loss through the leakage of steam past these sleeves. This loss is, however, not very great. We have used successful packings which give much less leakage, and they may be regularly adopted in future.

There is no lubricant of any kind used in connection with these packings, and since the bearings are external to the turbine base, there is no means by which oil can get into the steam. This is one of the greatest advantages of our turbine, and is an advantage which has not been fully realized in turbines of other makes. In most of the plants which we have installed, water is being returned directly from the hot-well to the boilers, and there is no waste of water or accumulation of dirt or scale in the boilers.

Mr. Curtis has made arrangements for reversing turbines of this type by using a separate set of buckets on the same wheel designed to receive steam from an opposite direction. These reversing buckets would ordinarily be applied to the wheels which operated in the vacuum space, so that in reversing, the machine would operate as a single-stage condensing machine.

The driving power of the turbine is confined to the buckets which come opposite to the nozzles which are in flow, and these nozzles occupy only a portion of the circumference, except in the last stage, where they generally occupy all or nearly all of the circumference. There is no unbalancing of the wheels caused by the delivery of steam to one segment at a time.

The steam required to drive auxiliaries will depend upon local conditions. In the 5000 kw installation at Chicago, all of the auxiliaries are driven by a single-cylinder Corliss engine, and this engine delivers 70 indicated horse-power when the 5000 kw machine is running at full load.

I cannot give any definite statement as to the degree of superheat which may be economical. I am inclined to think that where superheat is provided by increased heating surface in the boiler, it will be found economical to use considerable degrees of superheat, possibly 150. I will have much more information on this subject within a short time, and would rather not express a positive opinion at present. Every turbine shows a different degree of improvement by superheat. In some machines the advantage is undoubtedly small, while in others it is certainly very great.

We have built a very successful direct-current machine for our 500 kw turbine, which operates at 1800 revolutions per minute. This machine is of a very radical type and its success shows the possibility of much other work in the same direction. I cannot say just what the possibilities are, but I am inclined to think that we can successfully apply direct current machines to most of the turbines which we have built for alternating work, and that the results from these machines will be very satisfactory.

# ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, January 2, 1904.—President Edwin F. Smith in the chair. Eighty members and visitors present.

Announcement was made that Mr. John T. Loomis had been appointed by the Board of Directors to fill the unexpired term of Mr. D. A. Hegarty, who resigned from the Board on account of his removal to New York.

Professor Edgar Marburg opened a topical discussion on "Concrete: Its Properties and Applications," followed by Messrs. Charles M. Mills and Henry H. Quimby. Communicated discussions were presented from Messrs. George S. Webster and Charles H. Umstead, the one from the latter not being read because of the lateness of the hour, but was referred to the Publication Committee for printing.

Annual Meeting, January 16, 1904.—President Edwin F. Smith in the chair. Eighty members and visitors present.

The annual report of the Board of Directors and that of the Treasurer were presented, accepted, and ordered to be filed.

The Treasurer reported the names of three active members dropped from the rolls for arrears in dues to the Club.

Mr. Edwin F. Smith, retiring President, read the annual address, giving a brief résumé of the progress of the Club during the past year and "Some Early Engineering Works in Pennsylvania."

The Tellers reported the election of the following officers for 1904: President, Carl Hering; Vice-President, Thos. C. McBride; Secretary, J. O. Clarke; Treasurer, Geo. T. Gwilliam; Directors, George C. Davis, Washington Devereux, and Wm. Easby, Jr.

The new President, Mr. Carl Hering, called attention to the growth in attendance at Club meetings and the necessity for more room.

Regular Meeting, February 6, 1904.—President Carl Hering in the chair. One hundred and two members and visitors present.

Mr. John M. Hartman presented a paper entitled "How to Burn Bituminous Coal Properly." The subject was discussed by Messrs. Christie, Perrot, Nichols, and Bright.

Business Meeting, February 20, 1904.—President Carl Hering in the chair. One hundred and forty-six members and visitors present.

Mr. Emile G. Perrot presented a paper on "Reinforced Concrete in Building Construction."

The Tellers reported the election of Messrs. Frank E. Hahn and F. H. Stier to active membership, Messrs. Stanley G. Child, St. G. H. Cooke, Thorsten Y. Olsen, and Samuel P. Yeo to junior membership, and Messrs. C. W. Edmonds and B. H. Tripp to associate membership.

Regular Meeting, March 5, 1904.—President Carl Hering in the chair. One hundred members and visitors present.

Dr. Henry Leffmann opened a topical discussion on "Conflagrations in Cities," which was participated in by Messrs. William McDevitt, Furber, James Christie, Comfort, Quimby, Schumann, and others.

Business Meeting, March 19, 1904.—President Carl Hering in the chair. One hundred and fifty-five members and visitors present.

Announcement was made that the American Society of Civil Engineers extended an invitation to the members of the Club to avail themselves of the conveniences to be provided by that Society at the St. Louis Exposition.

Mr. W. L. R. Emmet, visitor, presented a paper on "Recent Turbine Developments."

The Tellers reported the election of Messrs. Frederick Conlin, Robert C. Hill, James Beach Ladd, Edward S. Morrell, John Albert Vogleson, and John William Wright to active membership, and Thomas Norris Box to junior membership.

# ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, January 2, 1904.—Present: President Edwin F. Smith, Vice-Presidents Comfort and Foster, Directors Myers, McBride, Riegner, Leiper, Bonner, and Loomis, the Secretary and the Treasurer.

The Treasurer's report showed:

| | |
|---|---|
| Balance, November 30, 1903, | $748.79 |
| December receipts, | 1299.84 |
| | $2048.63 |
| December disbursements, | 736.03 |
| Balance, December 31, 1903, | $1312.60 |

The report of the Executive Committee was accepted and ordered printed.

The Janitor's salary was advanced from $45 to $47.50 per month, dating from January 1, 1904.

Mr. I. W. Hubbard was made a regular teller to fill the place made vacant by Mr. John T. Loomis.

Regular Meeting, January 16, 1904.—Present: President Edwin F. Smith, Vice-President Comfort, Directors Riegner, McBride, Bonner, Leiper, Loomis, the Secretary and the Treasurer.

A letter from the Girard Estate explained the necessity of increasing the rental of the house $161.00 on account of increased tax rate, to take effect upon the termination of the present lease, June 30, 1904, thus making the total rental $1261.00 per year.

Letters of resignation from the following were presented and accepted: Messrs. John Overn, Conway B. Hunt, John C. Nowell, John DeGray, W. L. Wright, Elmo G. Harris, and D. J. Matlack.

Organization Meeting, January 23, 1904.—Present: President Carl Hering, Vice-Presidents Foster and McBride, Directors Leiper, Loomis, Davis, Devereux, and Easby, the Secretary and the Treasurer.

The President announced the appointment of the following committees: *Finance*, Messrs. Horatio A. Foster, James B. Bonner, George C. Davis; *Membership*, Messrs. James B. Bonner, Horatio A. Foster, Wm. Easby, Jr.; *Publication*, Messrs. Wm. Easby, Jr., Thos. C. McBride, James B. Bonner; *Library*, Messrs. Geo. Neville Leiper, Washington Devereux, George C. Davis; *Information*, Messrs. Thos. C. McBride, Wm. Easby, Jr., John T. Loomis; *House*, Messrs. John T. Loomis, Geo. Neville Leiper, Washington Devereux.

Mr. Edwin F. Smith was appointed a member of the Committee on Relations of the Engineering Profession to the Public, to take the place made vacant by Mr. Hering.

The Tellers of Election were appointed as follows: William E. Bradley, Chairman; I. Wendell Hubbard, Francis Head, H. P. Cochrane, Emile G. Perrot, and Alan Corson.

Auditors for 1904: Messrs. Dallett, Humphrey, and Spangler.

Special Meeting, February 6, 1904.—Present: President Carl Hering, Vice-Presidents Foster and McBride, Directors Bonner, Leiper, Loomis, Davis, and Easby, the Secretary and the Treasurer.

The subject of proposed club rooms in the Witherspoon Building was discussed.

Regular Meeting, February 20, 1904.—Present: President Carl Hering, Vice-Presidents Foster and McBride, Directors Bonner, Leiper, Loomis, Davis, Devereux, and Easby, the Secretary and the Treasurer.

The Treasurer's report showed:

| | |
|---|---|
| Balance, December 31, 1903, | $1312.60 |
| January receipts, | 1943.00 |
| | $3255.60 |
| January expenditures, | 338.41 |
| Balance, January 31, 1904, | $2917.19 |

The Boston Society of Civil Engineers was added to the list of clubs and societies exchanging club house privileges.

The Secretary was given complete authority to arrange and direct the work of the office and the assistant, so as to expedite the business of the Club.

A resolution was passed that it is the sense of the Board that discussions should be condensed for publication.

The arrangement of the circular notice of club meetings was referred to the

Chairman of the Publication Committee and the Secretary, after some consideration of the form of notice.

The President was authorized to appoint a Committee on New Club House, the size of the committee being left to his discretion.

The resignation of Mr. C. F. Moore was presented and accepted as of December 31, 1903.

The President was authorized to appoint a committee to take charge of the advertising of the Club.

Regular Meeting, March 19, 1904.—Present: President Hering, Vice-Presidents Foster and McBride, Directors Bonner, Leiper, Loomis, Davis, and Devereux, the Secretary and the Treasurer.

The President announced that the Committee on Advertising would consist of the Treasurer, Chairman of the Publication Committee, and the Secretary.

The Treasurer's report showed:

| | |
|---|---|
| Balance, January 31, 1904, | $2917.19 |
| February receipts, | 577.50 |
| | $3494.69 |
| February disbursements, | 709.31 |
| | $2785.38 |

The question of securing members of the American Society of Civil Engineers resident in Philadelphia as members of the Club was referred to the members of that Society who are now members of the Club.

An appropriation of $200 was made to the House Committee with directions to proceed at once with proposed changes in the partitions on the first floor.

The President was authorized to appoint a committee to devise ways and means by which the Club could co-operate in the movement of the City Parks and other allied organizations for a report on a comprehensive park system for Philadelphia, the chairmen of the Information and Publication Committees to be made members of the Committee.

The President was authorized to appoint a special committee on information which is to make the Club House headquarters where all visiting engineers may obtain information as to the points of interest in the city and a list of manufacturing establishments, etc., which may be visited, the President to be ex-officio member of the Committee.

The invitation of the American Society of Civil Engineers to members of the Club to avail themselves of the conveniences to be established by the Society at the St. Louis Exposition was accepted and directed to be read to the Club.

A request that members of the Club join the International Engineering Congress, to be held in St. Louis, was directed to be presented to the Club at the next business meeting and sent out in abstract in the notice.

The resignation of Mr. Walter S. Sheafer was accepted.

# ADDITIONS TO THE GENERAL LIBRARY.

From University of Pennsylvania.

The Provost's Report, August 31, 1903.

From State Board of Health of Massachusetts.

Thirty-fourth Annual Report, 1902.

From Commissioner of Education, Washington, D. C.

Annual Report, 1902, Vol. II.

From Carl Hering, Philadelphia.

Report of "Dinner to John Fritz, October, 1902."

From George W. Rafter, Rochester, N. Y.

Report of the State Water Storage Commission, New York, 1903.

From University of Texas Mineral Survey.

Report of Progress for the Year Ending December 31, 1903.

From Bullock Electric Manufacturing Co., Cincinnati, Ohio.

Relative Advantages of Electrical and Mechanical Methods of Variable Speed Control for General Power Service.

From William Cooper, Cincinnati, Ohio.

Methods of Speed Control.

From John Birkinbine, Philadelphia.

The Production of Iron Ores in 1902.

From University of Pennsylvania.

Proceedings of University Day, February 22, 1904.

From Robert G. Dieck, Manila, P. I.

Report of the Municipal Board of the City of Manila, June 30, 1903

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS

OF

# THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXI. JULY, 1904. No. 3

## FAILURE OF OAKFORD PARK DAM ACROSS BRUSH CREEK NEAR JEANNETTE, PENNSYLVANIA.

HARRISON SOUDER.

*Read April 2, 1904.*

## ERRATUM, VOLUME XXI, NO. 2.

Page 146, ninth line from bottom, read

$$x = 20y\left(-1 + \sqrt{1 + \frac{1}{12y}}\right);$$

instead of

$$x = 20y\left(-1 + \sqrt{1 + \frac{1}{12}y}\right).$$

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FROM CARL HERING, PHILADELPHIA.

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Report of the State Water Storage Commission, New York, 1903.

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Vol. XXI. JULY, 1904. No. 3

# FAILURE OF OAKFORD PARK DAM ACROSS BRUSH CREEK NEAR JEANNETTE, PENNSYLVANIA.

HARRISON SOUDER.

*Read April 2, 1904.*

On Sunday afternoon, July 5, 1903, the dam across Brush Creek at Oakford Park, about one mile from Jeannette on the Pennsylvania Railroad, was washed out, causing the loss of twenty lives at Jeannette, Greensburgh, Manor, Penn, and Irwin, small towns below. At the time of my inspection on July 12th, the condition of the wrecked dam was practically unchanged.

An employee of the traction company that owned the park, who was an eye-witness of the catastrophe, stated that there were two heavy downpours, or "water-spouts" as he called them: the first, at four o'clock, caused the water to rise rapidly in the reservoir and overflow the dam. The watchman immediately opened the twenty-four inch drain-pipe and then warned the many visitors in the park of their danger and tried to get them to leave. Then came the second cloud-burst which finally carried the dam away at about half past four o'clock. The water was running over the dam fully twenty minutes before it broke, it was stated, and an inspection of the dam on July 12th, would indicate that this was so.

The dam was an earth structure, three hundred and twenty-one feet long and fourteen and one-half feet wide on the top. Both slopes

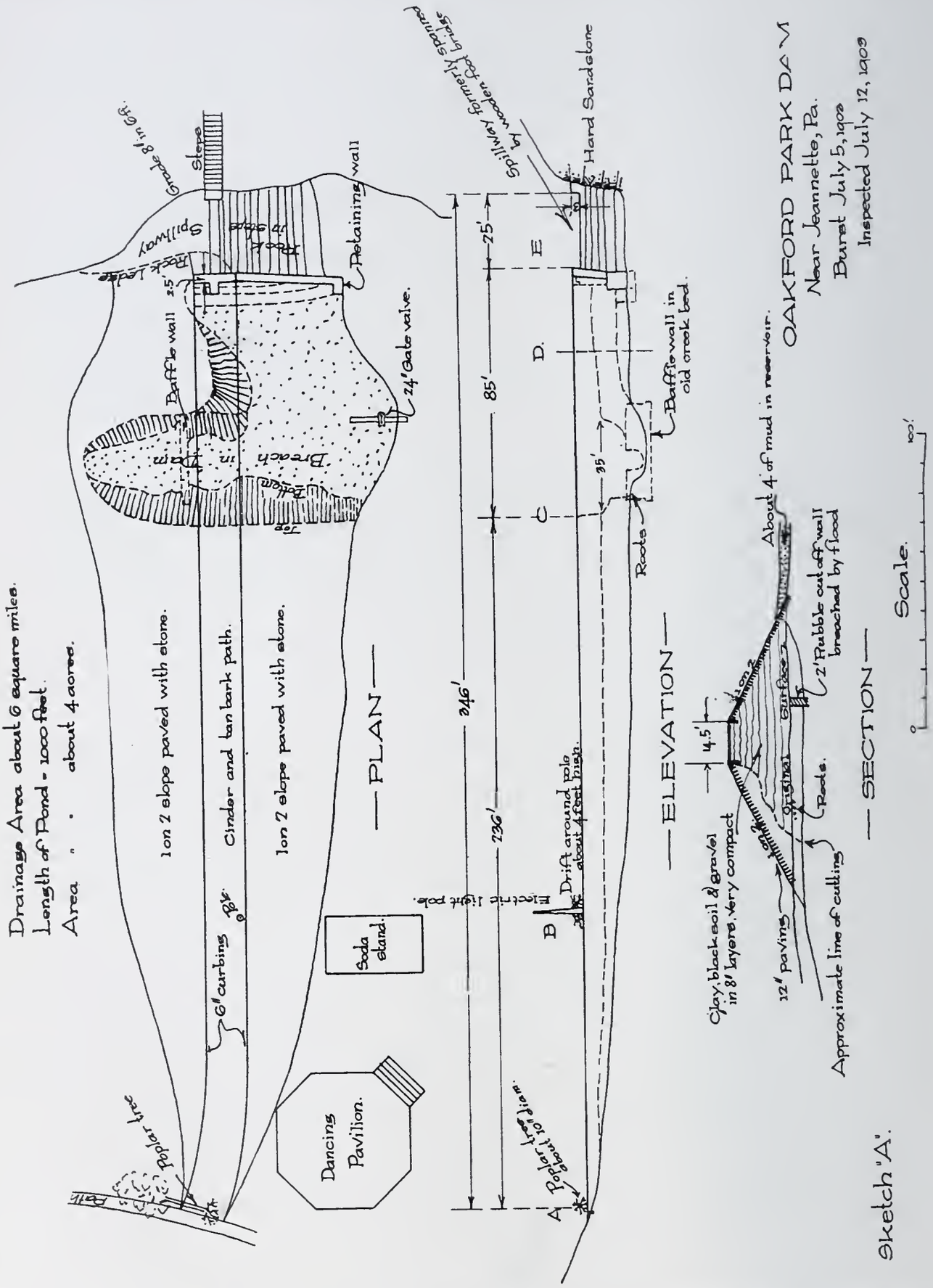


FIG. 1.

were one on two and were paved with flat rubble stones averaging

four inches thick, twelve to twenty-four inches long, and twelve inches deep, laid on edge. The paving on the slopes was laid dry. The dam was approximately twenty-five feet high above the bed of Brush Creek; the reservoir being one thousand feet long and covering an area of some six acres, with a maximum depth of water of twenty feet. A plan, elevation and cross-section, are shown in Fig. 1, the position of the breach being shown in broken line .

The break in the dam extends from the spillway retaining wall to a point, C, eighty-five feet to the left. The maximum cut is ten feet wide at the bottom and thirty-five feet at half the height of the embankment, and occurs at the old creek channel. From this point to the spillway wall a portion of the inner slope of the embankment remains.

The maximum cross-section at the creek bed appears in Fig. 1. This shows a rubble masonry wall two feet thick of small stones in cement mortar of poor quality, which was built across the old creek bed only, about twelve feet up-stream from the center line of the dam, and is carried up to the top of the creek banks only. This wall was breached. The presence of many roots "in place," where the natural surface is exposed, would indicate that the original surface was not stripped clean, if at all.

The embankment was built of eight-inch layers of clayey loam, black soil, and gravel, and was hard and compact, the lower face where cut out by the overfall of water standing almost vertical. There was no core wall or puddle lining. Fig. 2 is a view of the embankment at the point of maximum cutting, and shows also the construction in layers.

The spillway, three feet deep and twenty-five feet wide, was mostly cut out of a hard, solid sandstone ledge. A heavy masonry retaining wall founded on rock separated the spillway from the earthwork. The inner approach to the spillway, next the wall, was paved with stone in cement, the grade being eight inches in six feet. This paving was undermined, forming a cave between the wall and the rock, some eight feet wide and three feet high, from which the earth had been washed (see Fig. 3), exposing a masonry wall extending across the spillway from the retaining wall to the rock ledge. The spillway crest is level, three feet wide, and formed of large cut stones. The fall away from the crest is cut out of the rock in nine-inch steps at the top, growing larger at the bottom, the average slope being about forty-five degrees.

The retaining wall is two and one-half feet wide on top, increasing

Fig. 2.—General View of Broken Dam.

to five feet at fourteen and eight-tenths feet down; where it is benched to eleven feet in width. There was no attempt at a baffle wall, except a meager one at the top, to break the smooth bond between the masonry and the earth embankment. The smooth character of this wall is shown in Fig. 3.

The water first began to run over the dam at point A, Fig. 1, where a slight depression was formed by a path on the natural ground. The water overflowing increased in depth, finally washing away all the outer slope paving, and must have continued to flow over the entire

Fig. 3.

length of the dam for some time, as evidenced by the cutting out of the earth slope to a depth of six or eight feet, leaving it standing nearly vertical, as shown in sketch and photographs.

While reports state that the water was ten feet or more in depth on the breast, this was not possible. This amount of water would have carried away the dancing pavilion and soda-water stand immediately below the dam; while, as a matter of fact, it did them no great damage. An electric light pole at B, Fig. 1, right on the crest of the dam, was not carried away. A tree with its roots, at A, and

the drift, possibly four feet high, around the electric light pole, at B, would indicate a probable maximum depth of three feet, and not possibly over five feet, on the crest.

All accounts seem to agree that the first break began at the spillway wall, which is most probable, and extended rapidly until the break reached a width of eighty-five feet, as shown in Fig. 1.

The coroner's jury rendered a verdict to the effect that those that lost their lives in the vicinity of Oakford Park on July 5th, came to their deaths through "an unusual downpour of rain"; except one person electrocuted by grasping a live wire. The jury seemed satisfied that the fatalities were not directly due to the breaking of the dam.

The spillway was three feet by twenty-five feet, with an area of seventy-five square feet. If we assume the depth of water on the crest of the dam to have been three feet, the total sectional area of water flowing over it was 1125 square feet: Using Francis' formula for discharge over wide-crested wiers, $Q = 3.012\ L\ H^{1.53}$, which would nearly apply to this case, we have a discharge of 6462 cubic feet per second. The drainage area was approximately six square miles, giving a discharge of 1077 cubic feet per second, per square mile. At the coroner's investigation it was stated that $5\frac{1}{8}$ inches of rain fell in the neighborhood of the dam on the afternoon of the flood; it was also shown that the dam did not break until fully two hours after the rain began to fall. A rainfall of $5\frac{1}{8}$ inches on six square miles is equivalent to 7,866,936 cubic feet of water = 1092 cubic feet per second = 182 cubic feet per second per square mile. It is probable that the greater part of this rain came down in a brief period of time —less than an hour—and the maximum flow over the dam lasted but a short time; it would also indicate that it is hardly probable that the depth of water on the crest of the dam exceeded three feet.

Fanning's formula, $Q = \frac{200\ M^{\frac{5}{6}}}{M}$ = cubic feet per second per square mile, gives 162 cubic feet per second per square mile. The spillway running full, level with crest of the dam, discharged but 131 cubic feet per second per square mile, so that the spillway was not even large enough for average flood conditions.

It is my opinion that uch a storm as this cannot be taken care of by the spillways provided in common practice, especially for small dams with small drainage areas. Small dams provide comparatively little storage room, and the drainage area being so small, the great local

downpours have no chance to spread and their effect is quickly felt at the dam.

Such dams should be of timber or masonry and provided with a roll-way, or apron, so that they can discharge water over their entire length. If they are built of earth, then an extra large spillway, more than sufficient to carry the greatest known floods, should be provided, and a substantial core wall built the entire length of the dam and well into the hills on either side, and extended up at least to the spillway crest elevation and down into hard bottom.

A suitable masonry core in this dam, acting as a retaining wall, would possibly have saved the great loss of life and property.

A small earth mill dam some ten feet high, in the neighborhood of Jeannette, which had a masonry core wall, was overflowed by the same storm. The wall and inner embankment remained intact, while all the earth behind the wall was washed away.

The flood wave, rolling down the Brush Creek valley after the dam gave way, swept all the frame buildings in its path, overturned several trolley cars and broke down the brick wall at the end of the car barn. One of the trolley cars, full of people, was standing on a small stringer bridge over Brush Creek at the car barn, fifteen hundred feet below the dam. The greatest loss of life was caused by the overturning of this car.

The wreckage was carried down stream to the high embankment of the Pennsylvania Railroad, hindering the discharge of water through the masonry arch of twenty feet span and 217 square feet area of opening. The water rose against the embankment approximately thirty-five feet, forming a pool of probably twenty acres in extent, and lifted barns and houses from their foundations. The velocity of the water shooting out from the lower side of the stone arch under a head, tore away the solid masonry arch rings for some fifteen feet or more, along with the earth fill; leaving one of the railroad tracks suspended in the air.

## DISCUSSION.

Edwin F. Smith.—Mr. Souder has called our attention to the necessity of providing spillways. That is one of the essentials in building an earthen or mound dam; too much attention cannot be given to it. The spillways should, if possible, be so designed that with a maximum flood there will not be a greater depth of water than three and a half feet passing over it, and the embankment should be raised at least eighteen inches above the height of the maximum flood. An embankment only two and a half feet higher than the level of the

spillway, on such a stream is a toy and may bring about disastrous results, as the one under consideration did. It should be designed to pass with safety, the maximum discharge that may be expected, under any conditions, from the particular drainage area with which we are dealing.

Now, as to core-walls, there are many earthen dams built without core-walls, many of them being constructed before there was any such tool as a grooved roller. I do not like to use a grooved roller, or any device that will bring about such treatment of an embankment, intended to hold water, as is indicated in the well-defined layers shown in the illustrations on the screen. All such embankments should be made as nearly as possible homogeneous, either by tamping or careful rolling. The material should be thinly spread and kept sufficiently wet to insure packing, when put to place by tamping or rolling. There is too much disposition, in reservoir specifications, to define the thickness of layers and to educate the contractor or builder into the making of well-defined layers. It is a quick and less expensive mode of construction than that which I have indicated, but in many cases it does not result in good work.

The practice in India was to tamp the moistened material into place by men tramping over it with their feet, and another way was by driving cattle over it, thus making it a homogeneous mass. On those works, some of which are of great age, they did not use rollers.

Another thing which impresses me is the condition of the wing-wall of the spillway. That certainly was not a good piece of work. There is no evidence whatever of any cut-off walls or any devices for preventing the water from following the wall where it joins the embankment. There should always be at least two cut-offs introduced between the backing of the wall and the embankment, and the earthwork should be more carefully tamped around these cut-off walls than anywhere else. That is important, because we must expect that water will seek the easiest channel and endeavor to get through any space, however small, between a wall and an embankment.

There is no doubt that in the Jeannette Dam the water found its way through at that point. Again, there is no evidence of any attempt to prevent leakage under the embankment, except in the building of the small baffle wall across the creek. It would have been better, if before the building of the embankment, a deep trench had been excavated across the valley and that had been well puddled in. For a dam of moderate height this would have answered all the purposes of a core-wall, but the work must be well done.

I think it may fairly be said, in conclusion, that the prominent weaknesses of the Jeannette reservoir were:

1. The failure to provide sufficient area of spillway.
2. The insufficient height of embankment above the level of the spillway.
3. The making of the embankment in well-defined layers.
4. The failure to introduce "cut-off" walls into the masonry, and especially the walls of the spillway.

Mr. Souder.—I agree with Mr. Smith that an earth dam should not be built in continuous horizontal layers running through the embankment. It is the usual method, but not a good one. There are several ways of breaking the continuity of the layers. It seems to me the method of tamping and compacting with the feet is rather slow and ancient. Good work has been done

in that way, but it takes a much longer time for the embankment to settle than if the earth is rolled uniformly while building. With the grooved roller breaking the layers, I think you can get very good work, if the earth is well wetted as you put the layers on, and I do not think there will be much danger of the water seeping through. The weight of the roller used is an important feature which has not been touched upon to-night. I prefer the heavy steam-roller, say 8 tons, for embankment work. You can do quicker work with a heavy steam-roller than with a light one, provided the other conditions are favorable. A light horse-roller should be kept on hand for use after rainy weather when the earth is soggy.

At Johnstown on the large Hinckston River Dam, of which the writer had charge, good work was done with a 10-ton steam-roller, the front roller being grooved, the rear roller wheels being smooth but studded with spikes. A 3-ton horse-roller was also in use on this work. For tamping puddle clay along the concrete core-wall pneumatic tampers under 60 pounds pressure were used.

Mr. Smith.—I do not want to be misunderstood about the use of a grooved roller. The practice is to rely too much upon a six or eight-inch layer and then roll it down with a grooved roller. It is not good practice to construct reservoir embankments in rolled layers. The effort, on the contrary, should be to make a homogeneous embankment, without layers, and this can be done if the material is properly spread and worked. What I want to discourage is the system of carting in the material and spreading it in as heavy a layer as eight inches, and then, by the use of a grooved roller, compacting it, and in that way building up a succession of such layers.

John Birkinbine.—When the dam, which has been described, gave way, I had under construction five earthen and one masonry dam, and as two of these earthen dams were in the same general territory as the destroyed structure, I naturally desired to be posted as to the conditions which brought about the failure of this dam, because, although it was small and drained a limited area, it has its lessons. Mr. Souder's investigations were unfortunately handicapped by the fact that subsequent to the dam being destroyed a continued heavy rain washed away many of the high-water marks which otherwise would have given definite heights, etc. I obtained from another engineer who investigated the disaster, his records and photographs, and also conferred with a man who lived in the vicinity, and who intelligently noted the conditions which prevailed. From the various reports I am convinced that one of those locally severe storms, which we must provide for, caused the disaster.

In constructing dams or reservoirs two conditions must be anticipated, either of which may arise but once in a lifetime, and we must construct the dams, if they are to last, with these conditions in view. One of the conditions is a continuous rainfall for a number of days, but the amount of rain deposited in a short interval not being phenomenal. The Johnstown disaster in 1889 resulted from a continued rain for three days, during which the total precipitation was not double that which fell on a portion of Philadelphia in an hour and forty minutes. We had five and four-tenths inches of rain in this brief period, while at the time of the destruction of Johnstown the highest record for any part of Pennsylvania was between nine and ten inches deposited in three days, and that was on the eastern slope and not the western slope of the Alleghenies. The other

condition which we must anticipate is a local severe downpour, such as brought about the disaster under discussion. Fortunately meteorological conditions do not appear to make possible such phenomenal deposits of rain over large areas. Nearly simultaneously with the disaster at Jeannette I had recommended a liberal spillway for a storage dam in Colorado, which drains a limited area. We do not know just how much, because the watershed is among the peaks of the Rocky Mountains. The water surface of this dam is 9800 feet above sea-level, and the storage is 6500 million gallons. I was studying the conditions of possible freshets, in connection with an ample spillway. The dimensions suggested were considered unnecessarily large by the engineer who had the construction in hand and by others connected with the State department. While letters upon this subject were passing a local storm occurred between Colorado Springs and Pueblo. A stream called "The Fountain," which heads up near Pike's Peak, has ordinarily a dry bed. One afternoon there was a summer shower in Pueblo and also a similar one in Colorado Springs, thirty-five miles distant. Between these a cloud-burst occurred, and the little Fountain was turned into a raging river, which broke all railway communication between Colorado Springs and Pueblo for several days and washed away buildings and bridges. Near the city of Pueblo is another stream, Rock Run; ordinarily, if you need a drink of water, you must go elsewhere; but I noted marks of a freshet, which came down that creek, fully thirty feet deep and five hundred feet in width, and great rocks weighing five or six tons must have been moved a half mile or more. That stream obtained the volume of water from a prairie, on which one sees no declivity, to indicate which way the water runs. But every cactus bush had grasped around its roots the remains of the Russian thistle, showing that a decided current had passed over the plain; and yet adjacent streams had no freshet of any account. These local freshets encouraged the adoption of the liberal spillway capacity recommended.

Following the Jeannette disaster, I had the calculations for all spillways, which we had in hand, examined with the idea of correcting any possible errors.

I endeavored to obtain records from the United States Weather Bureau, but found nothing in the immediate vicinity of Jeannette. The nearest of the neighboring records taken by the Weather Bureau showed a contemporaneous rainfall of one inch or less. This indicates a local severe storm. The statement was made that at one house, well in the center of the drainage area of Brush Creek, a crock ten inches high standing outside the house was filled by the rain. In a part of Iowa where much of the Chicago, Burlington and Quincey Railroad was washed out, it was claimed that fourteen inches of rain fell in a day. This was a great storm—fourteen inches; but we had five and four-tenths inches in an hour and forty minutes in our own city. Mr. Codman has given to you the records of that very interesting storm, but some of the later ones may have taken away its laurels.

These are the two conditions to be met, and our spillways or overflow dams are not to be erected merely for the ordinary freshet: we must proportion them to take care of the volume of water which may come but once in a lifetime. We must either build dams to take water over the crest, or vent the maximum discharge past the structure by means of spillways of ample size. The masonry dam I had under construction drained an area smaller than that which has

been mentioned for the Jeannette dam. It has a crest 130 feet wide, over which water can flow to a depth of 4½ feet. Possibly the failure of some masonry dams has been due to the fact that proper consideration was not given to proportioning them to the velocity of the water passing over the crest. We make what we call an ogee on the down-stream face, on the theory that a certain amount of water will go over a dam built amply strong to sustain any weight behind it. A reason for failure of dams similar in design to that at Austin, Texas, may be found in the high velocity due to abnormal volumes in times of freshet, which carries the water clear of the crest, allowing it to fall upon the lower part of the ogee, or upon the apron, with terrific force.

I agree with Mr. Smith that embankments in layers are not desirable, and I never used the word "layer" in specifications. But I do not agree with Mr. Smith's objections to grooved rollers. I prefer them, and think that their use secures a homogeneous bank. To use cattle is the worst thing for a bank, for the animals deposit on it foreign material. In the construction of earthen reservoirs we provide boys to follow the horses and pick up all droppings. We provide that the material shall be thinly scattered, and that the roller shall constantly traverse it. We require selected material well compact for the inner portion, and equally well rolled material for the outer portion.

As to core-walls: If a reservoir is tight on the inner portion, we may say frankly, what is the use of a core-wall? and if the core-wall is to be the water-tight face, what is the use of the interior portion of the embankment? Core-walls serve a very good purpose, as a barrier against any possible leakage in the earthen embankment, but I would not design a core-wall as part of an embankment unless I could put backing enough behind it, which, added to its own weight, would stand any anticipated pressure. In the construction of the reservoir in which Mr. Souder has been associated with me, we are using a concrete core-wall and backing it up thoroughly on both the inside and the outside. The core-wall extends for two-thirds of the vertical height of the embankment, and it will serve its purpose, but I never expect any considerable amount of water to reach it. It is there as a safeguard against accident. I have two dams under construction near Johnstown, Pa. The dam just described will hold over eleven hundred million gallons; the other about three hundred million gallons. Naturally a community which has suffered, as Johnstown did, is critical as to any artificial construction to store water, and yet the South Fork Dam, an earthen structure, did not fail until water had poured over the top of it for three-quarters of an hour. The destruction of life and property was primarily due to the fact that before the dam gave way Johnstown was under five feet of water, and people who wanted to, could not leave their homes. That dam, except for the portion which has been cut away, is to-day an evidence of what an earthen embankment can be expected to stand. One dam now building drains about six square miles; the spillway provided is constructed with concrete, but a wing-wall, as a continuation, is carried into the natural ground, and the surface leveled off, so that the length of the crest is three times that of the spillway proper. This extension being several feet higher than the spillway, will never come into service until the water is high enough to fill the spillway and then pass over this additional wing-wall. The objection is that a spillway in earth encourages vegetable growths which clog it. It is proposed

to thoroughly salt the exposed portion of earth excavation, and resalt it in future at such intervals as may appear best. If the vegetation is allowed to grow up it may become an artificial dam, and the spillway is of practically little use.

John E. Codman.—I can give statistics relating to the run-off of streams only so far as I can recall from memory. On the Perkiomen, which has a water-shed of 152 square miles, the greatest amount of run-off is about 110 cubic feet per second per square mile, continuing probably from fifteen to twenty minutes. On the water-shed of the Neshaminy—139 square miles—the flow-off is pretty nearly the same. The great storm which occurred in October, 1903, when we had the greatest freshet known on the Delaware, gave a precipitation, in some places in the Delaware valley, of from six to seven inches in thirty-six hours, and the amount of flow-off did not reach quite 100 cubic feet per second per square mile for the small streams. On the Schuylkill, the record, I think, was about 82 cubic feet per second per square mile. The small streams with water-sheds running from 100 to 150 square miles, with heavy rains and frozen ground, will reach their maximum in a very short time; the flow reaching a maximum in about eight to ten hours. In making computations for the size of the spillway for small streams, there must be some provision made for the sudden run-off. It does not remain for a great length of time; but when it does come, the vast amount of water must be provided for. If the spillway is not large enough, as in the case at Johnstown, of course, the flow is over the top of the bank.

J. W. Ledoux.—According to my memory, at Kittanning Point on Burgoon's Run during the rain-storm that caused the Johnstown flood there was a flow of water over the embankment and spillway corresponding to at least 400 cubic feet per second per square mile. The drainage area above this reservoir is 6 square miles and the watershed is almost entirely covered with woods. The embankment is about 900 feet long and the spillway on the south end is 34 feet long and 5 feet 3 inches high; the section of the crest being curved down-stream in the form of a parabola. The dam is entirely of earth, with a three to one slope up stream and two to one slope down stream, both slopes being covered with 12 inches of rip-rap with the surface broken to about 3 inches in size. The embankment was built of earth, using a sprinkler and a grooved roller, the layers being deposited not to exceed 6 inches in thickness.

The water ran over the earth dam for several hours, the maximum depth being 12 inches, which gave a depth over the spillway of 6 feet 3 inches. The earth embankment suffered no material damage. I believe the rainfall at Altoona, six miles distant, was reported to be about eight inches in twenty-four hours.

Mr. Birkinbine.—The Commission which reported to the American Society of Civil Engineers fixed the maximum run-off during the flood at the South Fork Dam, at above 200 cubic feet per second per square mile, and I would not be surprised if the conditions near Altoona were as stated. The run has a smaller drainage basin and is on the eastern slope of the Alleghenies, which, as you know, received such a drenching that there was not a bridge left on the Juniata River. On the Conemaugh River the drainage was confined to a limited area below Johnstown. The Johnstown disaster was local and the freshet conditions were not so severe on the streams of the western slope as on those of the eastern slope.

# THE LOWER ROXBOROUGH PRELIMINARY FILTERS.

P. J. A. MAIGNEN.

*Read April 16, 1904.*

THE problem of purifying water for city supplies is at this time the most absorbing topic of discussion among engineers, municipal administrations and the public in general. The recent epidemics of typhoid fever and the demonstrated value of filtration as a means of reducing the loss of life from this dread disease have influenced public opinion to such an extent that money for filtration plants is being voted by the taxpayers and their representatives with scarcely a dissenting vote all over the country.

Numerous engineers have made a specialty of filtration, and some have attained positions as filtration consulting engineers only second to those of the great lawyers and renowned physicians.

Up to very recent years it was thought that the construction of reservoirs like those of East Park, Queen Lane and Upper Roxborough, in Philadelphia, would settle the question of water purification. Then came the advocates of the slow sand or English system of filtration, pure and simple, and the open partisans of rapid mechanical, or so-called American filters. These, in turn, were met by independent engineers, who pointed out numerous cases of failure with both systems. As late as June, 1903, one of the foremost experts in the art of filtration, Mr. George W. Fuller, in the Transactions of the American Society of Civil Engineers, expressed himself on the question as follows:

"While, as is well known, in the majority of cases, mechanical filters have not been operated in a manner to produce uniformly good results, it is a fact, which does not seem to be appreciated by many, that the majority of the larger (slow) sand filters in this country that have been operated for several years have also failed to reach the goal which may be expected of them, as is noted by any one who takes the trouble to examine carefully the typhoid fever experiences in cities which have (slow) sand filters, such as Poughkeepsie, Hudson, Little Falls, N. Y., Ashland, Wis., Rock Island, Ill., etc."

Concerning the use of sedimentation basins as a means of purifying

drinking-water, the well-known French Engineer, D'Arcy, fifty years ago, wrote as follows:

"Of all the means of rendering to waters their original clearness lost by the admixture of earthy matters in suspension, that which presents itself first to the mind, and the realization of which does not appear at first sight to offer the slightest difficulty, is to abandon such waters to absolute rest during a period of time long enough to allow the sediment to gather at the bottom of the reservoirs; but when we come to actual practice we meet obstacles which had not previously revealed themselves."

Among these obstacles are: First, the time necessary for the formation of the sediment. D'Arcy estimates this at eight or ten days' absolute rest, and he writes:

"Motionlessness of great masses of water during eight or ten days, combined with the heat and action of the air, may bring about in the water a rapid change for the worse, owing to the development of vegetable growth on the surface and to the putrefaction of the numerous insects which may fall from the atmosphere. What renders stagnant waters dangerous is the ease with which their temperature rises, and thus they become the seat of reactions between oxygenated gases and the hydrogenated and carbonated matters."

Second; the masses of water to be clarified by this process. To provide sedimentation basins for eight or ten days' absolute rest, it would be necessary to have two sets of reservoirs of eight or ten days' capacity each, so that one set might be filled while the other is being emptied. If the water is allowed to flow through the reservoirs in a continuous manner, their capacity ought, in order to produce the same result, to be equal to something like twenty days' supply.

To find land and money for such reservoirs is not an easy matter, and if it were, it would not be the best solution of the problem. Reservoirs are useful to dilute the first and worst water of a freshet, or to keep an available supply in case of accidents to the pumps or pipes, but as a means of purification, their value is comparatively small.

Third; the gradual accumulation of mud at the bottom of the reservoirs. The sediment which accumulates in reservoirs gradually reduces their holding capacity, and when in course of time it is found necessary to remove the accumulated mud it is expensive and at times most inconvenient.

It is usual in this country to credit reservoirs of twenty-four or forty-eight hours' capacity with the removal of 30 per cent. turbidity

and 40 per cent. bacteria. This may be correct as a general statement, and it is no doubt true of ordinary river-water in a normal state. At such times the suspended matters which cause the turbidity are of comparatively coarse nature and they fall easily to the bottom, and the bacteria do actually diminish in number. It has been generally

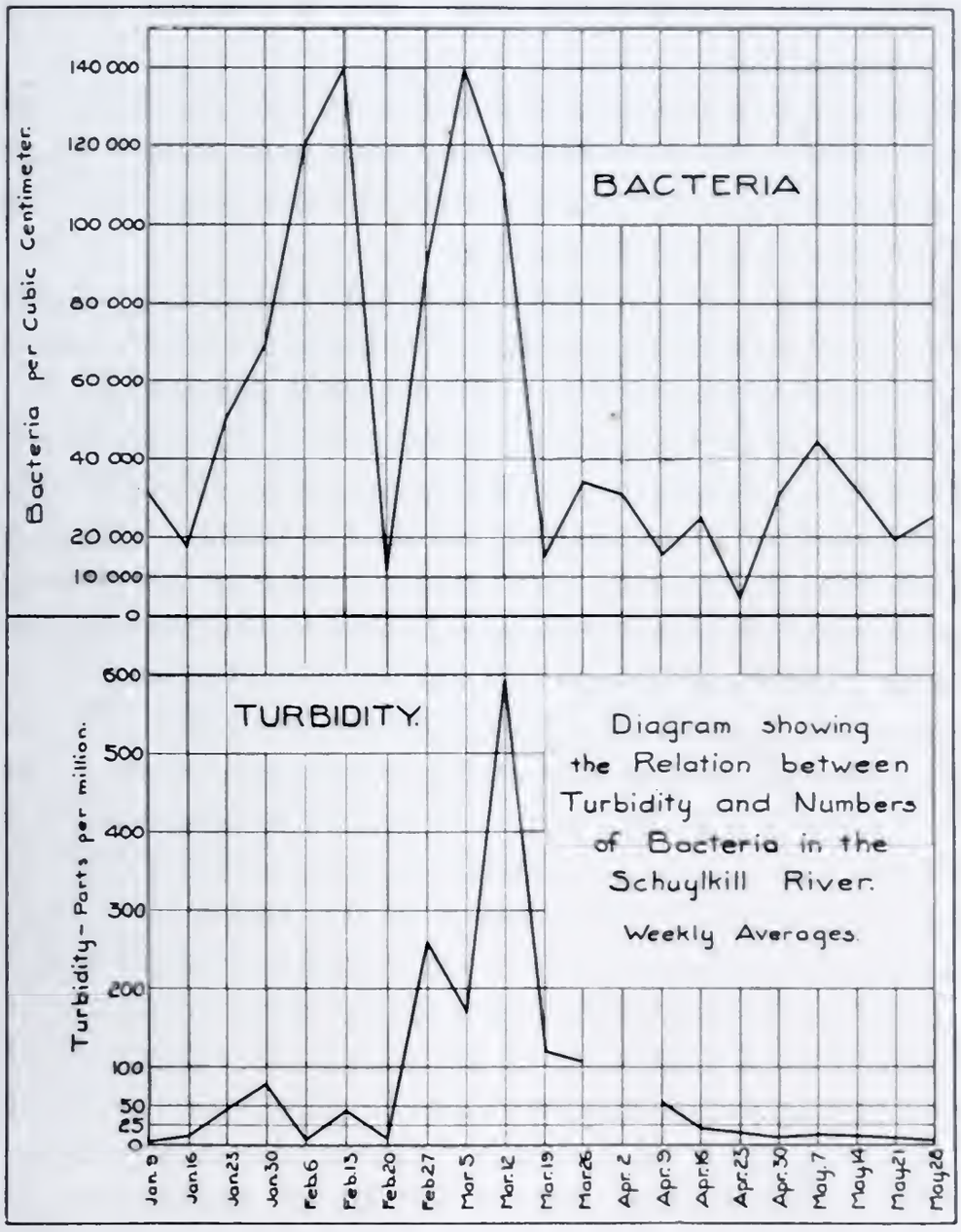


Fig. 1.

held during the last few years that the number of bacteria increases *pari passu* with the degree of turbidity of the water, both being brought about by the same cause, namely, the surface washings from rainfalls; but there are exceptions to this rule, and we have had this winter in Philadelphia a considerable deviation from it; for instance, the

river-water at the Shawmont Pumping Station during the period beginning January 4th and ending January 22d was very clear, having not more than 7 parts per million of turbidity, on an average, by the silica standard; at the same time the bacterial contents of the water averaged 43,000 per cubic centimeter. From April, 1901, to October, 1901, the average turbidity of the water delivered in Philadelphia from the reservoirs was 22 parts per million and the bacterial average 2,200 per cubic centimeter.

To explain this anomaly of low turbidity and the high number of bacteria is not an easy matter; it may have been caused by excessive sewage contamination coincident with the low stage of the river or some other cause not yet understood.

Another anomaly has presented itself this winter in connection with the Lower Roxborough Reservoir. The bacterial contents of the raw river-water as it came *into* the reservoir, from January 11 to April 9, 1904, averaged 64,000 per cubic centimeter. The water coming *out* of the reservoir, averaged during the same period 107,000 bacteria per cubic centimeter, or an actual increase of 67 per cent. This may be due to the fact that in the very cold weather, such as has prevailed, the higher organisms which are supposed to live on the bacteria were more or less absent from the water and did not interfere with their prolification, or it may be that the water, more or less agitated in the river, becoming quiescent in the reservoir, proved particularly favorable to the development of the bacteria. It should be observed in this connection that in all waters, particularly those containing organic matter, from the plain ordinary river-water to the highly polluted sewage, there is a considerable increase in the number of bacteria during the first twenty-four or forty-eight hours of rest, or quasi-rest, in whatever kind of reservoir or receptacle it be stored; they gradually diminish in number during the subsequent days, in proportion to the prolongation of the stagnant state. Another reason may account for this increase of the number of bacteria in the Lower Roxborough reservoir: that is, the fact that for several months previous to December 22d the reservoir had been emptied for the purpose of removing the four or five feet of mud which lay at the bottom. A small portion of the mud was removed, then work ceased and the reservoir was filled afresh, with the greater part of the original mud remaining at the bottom. It may be that the air germs which had fallen on the mud, or the original bacteria dormant in the old mud, found fresh vigor in the new water pumped into the reservoir. The same peculiarity was noticed

in experiments carried on in 1902 at New Orleans, and the worst results were also observed in the winter months.

The following table, taken from the "Report on Water Purification Investigation for New Orleans," by R. S. Weston, shows that "better percentage removals of bacteria were obtained after the water had been subsided for short periods than after long periods."

REMOVAL OF BACTERIA BY PLAIN SUBSIDENCE.

| Basin No. | Hours. | Average Bacteria per Cubic Centimeters. | | Bacterial Efficiency. |
|---|---|---|---|---|
| | | Influent. | Effluent. | |
| 1. | 72 | 2 000 | 3 900 | Increase.....95 per cent. |
| 2. | 48 | 2 200 | 5 500 | Increase.....150 " " |
| 3. | 12 | 1 900 | 1 300 | Reduction.....32 " " |
| 3. | 48 | 2 000 | 2 300 | Increase.....15 " " |
| 4. | 12 | 1 900 | 1 300 | Reduction.....32 " " |
| 4. | 24 | 2 200 | 1 900 | Reduction.....14 " " |

To return to the behavior of the Lower Roxborough water in passing through the reservoir; it should be stated that from April 11th to May 16th the water from the Schuylkill contained on an average 25,000 bacteria per cubic centimeter. After leaving the reservoir the number of bacteria in the water was on an average 11,500, or a removal of 54 per cent.

It may be noted that during the first period, from January 11th to April 9th, when the bacteria were apparently growing in the reservoir, they were being removed by the preliminary filters to the extent of 76 per cent., and in the second period, from April 11th to May 16th, to the extent of nearly 80 per cent.

Concerning slow sand filters, it is held by many that it is necessary to have a *schmutzdecke* or mud blanket on the surface of the sand, and that without it the filter is not complete or efficient. Others call this natural mud deposit a "filtering membrane," very fragile in character and easily broken by the slightest change in the pressure of the water above or suction below; hence the efforts made by many engineers to regulate automatically the flow of the water in and out of the filters.

The accompanying diagram (Fig. 2) shows the difference in turbidity found by two independent operators. The curves on the left

show the results from a single sample a day; those on the right are the results of four samples a day.

It has been usual during the last few years, in Philadelphia and elsewhere, to speak of three million gallons as the normal rate of filtration of the English plain slow sand filters. Upon investigation it

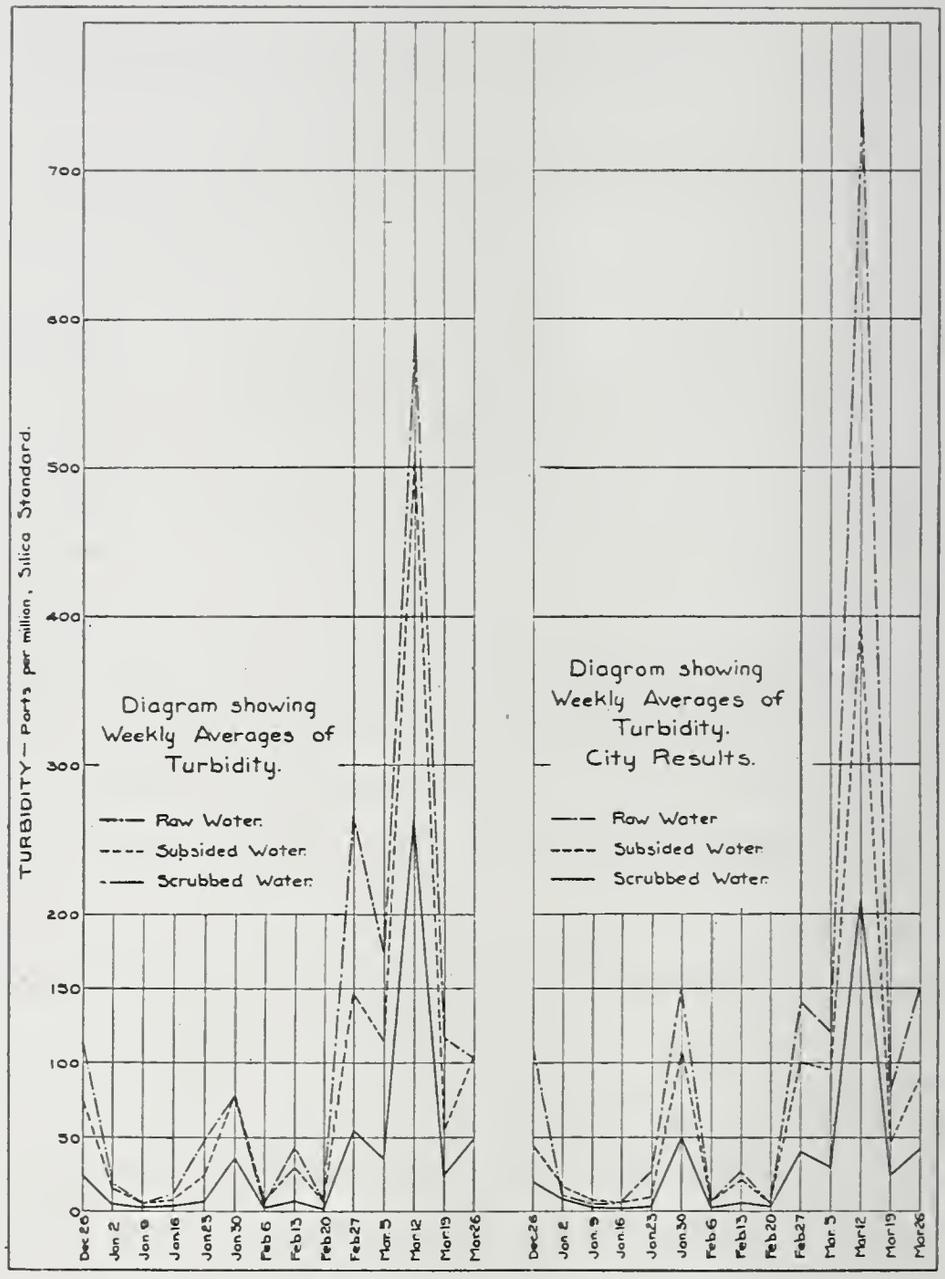


Fig. 2.

will be found that there is no evidence of any such rate having been attained in practice except in extraordinary cases, such as Zurich, where the influent is, according to Mr. Hazen, a "perfectly clear lake water." The same author states that "the Hamburg filters were only intended to filter at the rate of 1.60 million gallons per acre daily,

and are not allowed to filter faster." In London in 1868 the rate was 2.28 million gallons. In 1885 it was reduced to 1.61. In 1898, according to Mr. John W. Hill ("Public Water Supplies," page 259), the average London rate was 1.80 million gallons per acre per day. In one of his estimates for a plant of 10 million gallons capacity Mr. Hazen

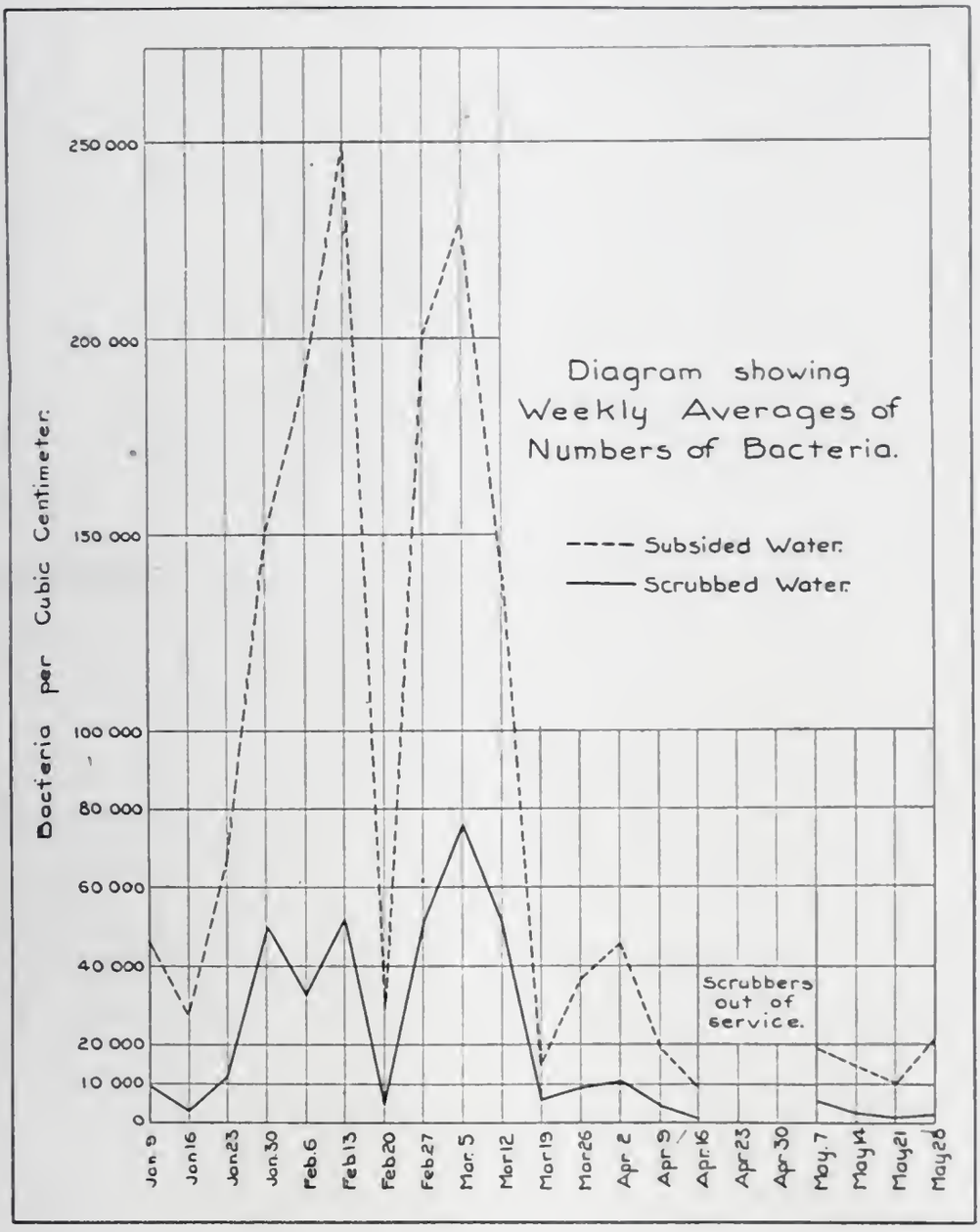


Fig. 3.

allows five acres in service and one acre reserve for cleaning, or a net rate of 1.66 million gallons per acre per day, on the assumption that all the filters are in service at one time, and 2 million gallons per acre per day if one of the 6 acres is out of service for cleaning. At Breslau, Altona, and Frankfurt, according to the same author,

the rate is 1.85 million gallons and the yield between scrapings 55 million gallons. At Bremen, Köningsberg, Brunswick, and Posen the rate is 1.34 million gallons per acre daily and the yield between scrapings 40 million gallons per acre.

According to Colonel Alexander M. Miller (letter to the Secretary of War on the feasibility and propriety of filtering the water-supply of Washington, D. C., page 17), "The average rate of filtration of the English system is 1,700,000 gallons per diem per acre." This being the case, it may be asked, on what basis can any one assume that the final plain sand filters in Philadelphia could give three million gallons per acre per day without preliminary filters, even if very large settling reservoirs were being used, which is not so, except in the case of Upper Roxborough? All of the English filter plants are provided with large settling basins; some of them hold as much as thirty days' supply or more, and yet the average rate there is, as stated above, less than 2 million gallons. It would, therefore, appear more correct to speak of the capacity of the plain slow sand filters as 2 million gallons per acre per day rather than 3 million gallons.

Concerning mechanical filters, the aim has been to force the water through the sand at very high rates, say, for instance, 120 million gallons per acre per day, or sixty times more than by the slow sand process. It can be easily understood that if it has been found necessary to limit the permissible rate of filtration through beds of sand to 2.5 million gallons per acre per day (in Germany higher rates are prohibited), satisfactory results can hardly be expected at a speed fifty times greater. In order to obtain clear water at such rates it is necessary to use coagulants—that is, to add alum or sulphate of alumina to the raw water in varying proportions according to its degree of turbidity; and it is now recognized that an insufficient quantity of coagulant makes the filtered water unsatisfactory in a bacterial sense, while an excess of coagulant makes it chemically objectionable and capable of injuring health in various ways; moreover, the addition of coagulant, by increasing the amount of suspended matter to be dealt with by the filter, shortens the period of service between two cleanings. It is usual to obtain from the slow sand filters 60 or 65 million gallons of water per acre between two cleanings, while with the mechanical filters, with coagulated water, it is seldom possible to get more than 40 or 45 million gallons; moreover, in the slow sand filters the sediment collects at the surface; in the mechanical filters, owing to the greater velocity of the flow of water, the sediment penetrates deep into the sand, and toward the end of the operation it goes right through.

In the slow sand filters it is sufficient to remove an inch or so of dirty sand from the surface; in the mechanical filters the whole volume of sand has to be raised by reverse current and agitated or otherwise handled in its entirety each time it becomes choked and refuses to work further.

In the slow sand filters the period between two cleanings averages twenty-five days; in the mechanical filters, eight hours; so that it can be clearly seen that it is not the quantity of water filtered that governs the period of cleaning but the amount and nature of the suspended matter which is in the water to be filtered; this, at times, becomes a very serious matter for both systems, but more particularly for the mechanical filters, because, while in the slow sand filters an increased quantity of sediment may shorten the runs by some days, in the case of mechanical filters it reduces them to hours. The number of extra mechanical filters, required as a reserve for such occasions, in order to maintain a given yield of filtered water, is variously estimated at from 30 to 75 per cent. in excess of what is necessary for normal water. (See pages 442 and 333, "Louisville Filtration Report," by George W. Fuller.) You will also understand that when a coagulant is used, as is the case with mechanical filters, all the year round, a considerable expense is entailed, not only for the chemicals but also for the operation and attendance.

The citizens of Philadelphia, through their public filtration committees under the initiative of Mr. Frank J. Firth and others, have long clamored for slow sand filtration. The experts appointed under the late administration have recommended this system as the best suited for Philadelphia water, but they have much underestimated the quantity of water for which filter plants ought to be provided. They have assumed that it would be possible, by the installation of meters, to reduce the consumption of water in Philadelphia to 200 million gallons daily. If it is assumed that Councils and the people are ready to agree to the compulsory use of meters, it would take many years and much money to install them. We would venture to suggest that at the present moment it would appear as if the taxpayers would rather pay more taxes than submit to meters. Meters or no meters, the city filter plants should be large enough to deal with the quantity of water *now* being pumped. For the year 1902 the average daily pumpage was 313 million gallons and the maximum daily pumpage 360 million gallons. In 1903 the average daily pumpage had risen to 327 million gallons and the maximum daily pumpage to 384 million gallons.

At this rate of increase, therefore, it would seem advisable to have filter plants at once for 400 million gallons daily. It is not enough to provide for the average consumption; the plant must be able to give the maximum quantity of water required on any one day. At present there are partly constructed or under contract in Philadelphia 94 filters of a total net filtering area of 68 acres. Assuming that one-sixth of this area is out of service for cleaning, there would remain 56.66 acres of filtering area in actual service. If the rate of filtration were fixed at the English standard of 1,600,000 gallons per acre per day, the 56.66 acres would give daily 90 million gallons; at the 2 million gallon rate, 113 million gallons; at the 2.5 million gallon rate, 141 million gallons, and at the 3.0 million rate, 170 million gallons, or less than half the quantity of water required in Philadelphia.

At Washington and at Pittsburg the filters have been planned on a rate of 2,200,000 gallons per acre per day. At this rate of 2,200,000 gallons, and taking the maximum quantity of water pumped in 1903, namely, 384 million gallons, there would be required in Philadelphia about 175 acres of net filtering area, as against 68 acres actually provided. Considering that the 68 acres with the purchase of land and all appurtenances will cost about $25,000,000, you can judge for yourself as to the amount of money that would be required to build filter plants nearly three times larger.

Mr. John W. Hill, the able engineer who has been entrusted with the gigantic proposition of improving the Philadelphia water-supply, has realized the necessity of doing something to increase the speed of filtration, and he has satisfied himself that preliminary filtration would meet the case. The author's ideas on the subject were submitted to the city of Philadelphia in 1900; they were investigated by Mr. Hill and by Messrs. Hering and Fuller, of New York. The results of this double investigation having been satisfactory, public competition was invited to supply a preliminary filter for the Lower Roxborough Filter Station. The author's bid was the lowest. You have seen the plant erected and working since October last.

In a report made on February 27, 1904, to the Finance Committee of the City Councils of Pittsburg, Mr. John W. Hill, Mr. Rudolph Hering, and Colonel Alexander H. Miller said:

"At Philadelphia preliminary filtration is a fundamental part of the present works, the chief object of which has been to reduce the area of filters required by permitting of an increase in the rate of filtration per unit of sand surface. Three objects are sought to be obtained by

preliminary filtration of the water before it is passed to the filters: (1) An increase in the rate of filtration per acre; (2) a prolonged (working) period of the filter with a corresponding reduced cost for maintenance; (3) a better control of the water applied to the (final) filters with the varying conditions of the raw river-water."

You have here in a few words the *raison d'être* of the Lower Roxborough preliminary filters; but there is a fourth object which appears to have escaped the experts above cited, and that is the maintenance of the efficacy of the final sand filters and the preservation of the best qualities of the sand layer.

Any one familiar with the management of slow sand filters knows that each time the sand is washed there is a separation and waste of some of the finer particles. The best grade of sand to use in plain slow sand filters is that which passes through a No. 14 sieve and is retained on a No. 60. In some cases all that passes through a No. 10 and is retained on a No. 80 has been accepted as satisfactory. The different grades between these two extremes are so well mixed in new sand that the fine particles fill the voids between the coarse particles nicely, and you can easily understand how a layer of new sand two or three feet deep makes a very good filter-bed capable of yielding a good quality of water at a relatively high rate—three or even four million gallons per acre per day; but this holds good only as long as the sand is quite new; when it has been cleaned several times some of the finest particles have been washed out and wasted with the mud, others have been blown away by the wind (if the sand has remained exposed in the courts any length of time), and as the number of washing operations increases, more and more of the fine particles are separated from the coarser, particularly with the system of the hopper washers now in vogue. On inspecting any of the latest plain slow sand filter plants in this country you can see, on the one hand, the washed sand, accumulated in the courts, visibly stratified; and, on the other, small heaps of very fine sand more or less mixed with mud gathered from the overflow gullets of the washing machines. This very fine sand is rewashed and thrown in with the coarser sand, but as you can readily understand, this artificial mixing is not so intimate as it was before washing; the consequence is that some parts of the filter-bed, when filled again with the washed sand, are composed of particles more or less coarse, while other parts contain sand more or less fine. In other words, the original quality of the sand has gone; it grows coarser and coarser after each washing, and it cannot give the same quality of

filtered water at the same rate as when it was new; a device, therefore, which is destined to reduce the number of cleanings of the sand, must of necessity be a most welcome help to the friends of slow sand filtration.

If the preliminary filters allow the final slow sand filters to yield 180,000,000 gallons of water between two cleanings instead of 60,000,000 gallons (the classical average of slow sand filters), and if we assume that the rate of filtration is the same in both cases, two cleanings out of three would be saved by preliminary filtration and the natural life of the sand, as an effective filter, would be increased three times. If the rate of filtration be doubled, the life of the sand will still be increased, and the per million gallon cost of renewal will be correspondingly reduced.

It has been stated somewhere that preliminary filtration was not new. I must take this opportunity to place on record that the kind of preliminary filtration carried on at Lower Roxborough is entirely new. The so-called fore-filters of Bremen and Schiedam are not preliminary filters at all. They are, as Mr. Hazen calls them, a double system of filtration; "the filters are all upon the same level and of the same construction." When a filter is put in service the effluent from it, instead of being taken to the pure water reservoir, is taken to another filter which has already been some time in service. After the first filter has been in operation for some time its effluent is taken to the pure water reservoir, and in turn it is supplied with the effluent from a filter more recently cleaned."

The Lower Roxborough preliminary filters or scrubbers are the first application of true preliminary filtration on a large scale at a high and economical rate, and it will no doubt interest you to have an explanation of the principles which have guided their conception as well as some of the details of construction and the results obtained.

## Principles Involved in the Lower Roxborough Preliminary Filters.

A new thing calls for a new name; pre-filter is the name given by the Bureau of Filtration; it has also been called roughing filter, preliminary filter, and auxiliary filter, but the name that would appear to best describe what is expected of this device and that which we prefer is "scrubber."

The Lower Roxborough preliminary filters or scrubbers are not intended to filter the water in the ordinary sense, the act performed is

more one of subsidence than of straining. In filters, generally, the materials used are supposed to have pores finer than the particles of suspended matter which they are intended to retain. In the preliminary filters or scrubbers under consideration the object sought has been to afford plenty of room for the accumulation of mud during long periods of time, without choking and without any appreciable loss of head. The pores or passages for the water are many thousands of times larger than the particles of suspended matter to be retained.

In the Lower Roxborough preliminary filters the water enters the bottom and rises upward through materials varying in size from 3 inches to 1 inch. Some of the filters are filled with furnace slag, others with coke. In future installations we shall recommend coke, because it has given somewhat better bacterial results.

On the top of the slag or coke, which occupies 41 inches in depth, there are 14 inches of sponge clippings held down by means of cedar slats suitably secured in place by yellow pine stringers, blocks, and steel I-beams.

The water leaves in the slag or coke materials and in the sponge layer about 65 per cent. of turbidity and about 80 per cent. of bacteria.

The water is distributed at the bottom of the bed through two lines of 6-inch pipes suitably perforated and shown in Fig. 8. It rises vertically through the materials and flows at the upper surface in an horizontal plane toward the outlet weir, which indicates the quantity of water filtered. Thus described, the device appears very simple, but it is not without considerable study and experimenting that this apparently simple contrivance has been evolved.

## Subsidence in Motion.

When it is desired to separate suspended matters from liquids by absolute rest, it is advantageous to have very shallow vessels or reservoirs. When these are deep, convection currents, encouraged by differences of temperature, are formed in the body of the water and create a motion which prevents the lighter particles from settling down; it is therefore desirable to have shallow reservoirs rather than deep ones in order to obtain the maximum amount of clear water out of a given amount.

Figures 1, 2, and 3 in plate I show this principle clearly. In figure 1 are three imaginary divisions, a a a, and if it takes, say, one hour for the solid matters to fall to the bottom of imaginary compartment A, it will take two hours to go down to the bottom of B, three hours to

the bottom of compartment C, and four hours to get to the bottom of D; if, however, there were three compartments with real divisions, b b b, as in figure 2, the sediment in A would be retained on the real division b in one hour, and as sedimentation would go on simultaneously in B, C, D, the whole tank full would be clear in one hour, because the sediment in one division would not interfere with the clarification in the other divisions; in other words, tank 2, with its real divisions, is equivalent to tank 3, which is four times wider but of the height of one of the compartments A, B, C, D.

The conclusion to be drawn from this illustration is, that as far as possible the water to be subsided should be divided in shallow layers; and what is true of water at rest, is equally true of water in slow motion.

In considering the sedimentation of water in motion certain principles are met with which are well worthy of consideration. You have all noticed, when standing on a bridge over a comparatively shallow river, how the flow of water between two piers, as for instance at A, figure 5 in plate I, acquires a great velocity because it is contracted into narrower limits by the piers themselves; immediately after this contraction it is divided in two sections, one scouring in a straight line and the other forming whirlpools and eddies behind obstructions, as behind the piers at B and in the open and quiescent parts of the river, where sand banks or islands are ultimately formed, as at C. In these parts the force of the current is spent; the water spreads itself over a comparatively large area; the eddy movements gradually lose their force and the particles of suspended matter settle down because their specific gravity is too great for the reduced velocity of the water.

The conclusion to be drawn from this observation is that instead of endeavoring to obtain an even motion in water undergoing the process of subsidence, it is better to submit it to various degrees of velocity, preferably by alternate contractions and expansions, so as to facilitate the formation of eddies, where the current loses itself and where the suspended matter can more easily settle.

The weight of the particles and the velocity of the water are the factors involved in subsidence. This is well illustrated in figure 4 in plate I, which represents in a crude form one of the methods of separating valuable metals in mining. The water flows down an inclined plane, and at different points in the canal, troughs or pools, as at A, B, and C, are provided of different capacities. The velocity of the water in passing through these troughs diminishes according to their areas, so that the gold, for instance, which is the heaviest metal, remains in

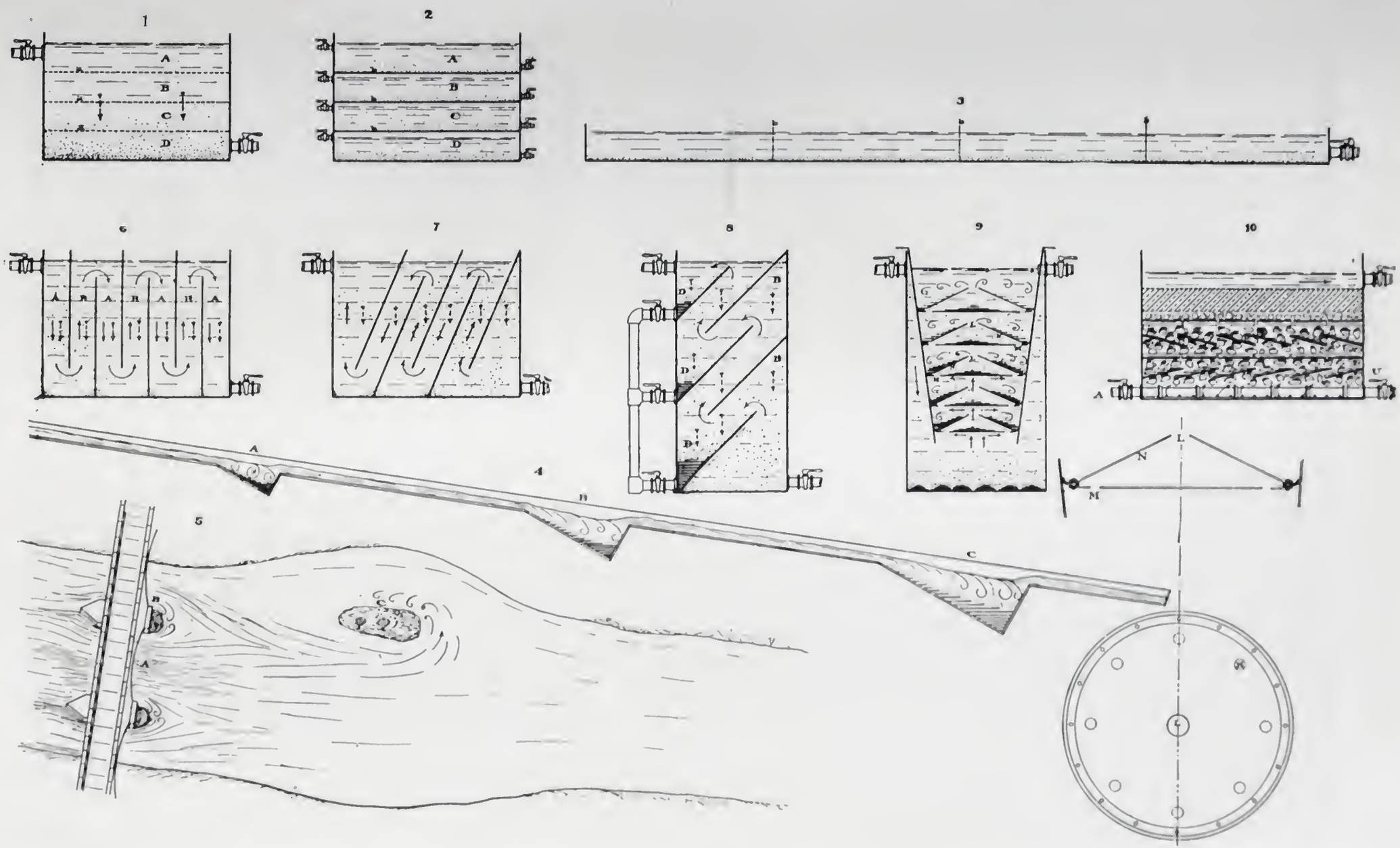


PLATE I.

trough A, while the lighter metals stop in troughs B and C, according to their specific gravity; the pulp or lightest material flows away to waste with the water.

Water has generally a tendency to travel in straight directions, like billiard balls, until it meets with obstacles; then it rebounds; thus it is that in reservoirs there is a tendency for the incoming stream of water to flow directly from the inlet to the outlet without mixing to any appreciable degree with the bulk of water surrounding it. The difference of temperature between the incoming water and that in the reservoir helps somewhat this direct flow, as is the case with the Gulf Stream in the Atlantic. It is, therefore, natural that engineers in charge of waterworks should have thought of devising means to check the flow of water in reservoirs by means of baffles or division walls. The idea of baffle plates has been utilized to a considerable extent in what is known as water-softening apparatus in England, France, and Germany. In this process of water purification chemical reagents are added to the water, a precipitate is formed, which if allowed to flow into a filter of any kind would choke it in a very short time, and the whole system would become impracticable on account of the excess of labor required to keep the filters in working order. Inventors, therefore, have designed a number of baffle systems of every shape and form. We will here show only three or four examples to indicate general principles.

Figure 6, plate I, represents a tank with plain vertical baffles in which the water travels down and up again. As the different partitions are equally distant from one another the velocity of flow is the same in all of them, and there is no reason why particles which do not settle in the first section should settle in the second. Floating particles which might have a tendency to settle in the first compartment are carried by and with the down-current. In the next compartment the same suspended particles are prevented from falling down by the upward flow of the water. The two contrary forces, upward flow and gravitation, neutralize one another practically all the way through the tank. This baffle tank is therefore more of the nature of an agitating device than a subsiding one.

In figures 7 and 8 plate I the baffles, instead of being vertical, are placed at different angles. There also the greater part of the space is lost to subsidence. The suspended particles are either carried down with the downward flow or prevented from falling by the upward flow. Only a small space at the lower angle of the baffle plates, shown by heavy

black lines, in figure 8, is quiescent enough to allow of real subsidence. Figure 9 plate I shows a system of baffles which the author has invented and which puts into practice several of the principles alluded to in this paper, namely—

The division of the water into shallow layers.

The increase and decrease in the velocity of flow.

The upward flow of the water with the greatest velocity is the upper film in each division, while the bulk of the water lags behind in the center of the hollow cones and around the cones, where it moves with a very slow eddy motion and is therefore in the best of conditions for subsidence.

This is easily seen by throwing a few drops of coloring-matter, such as potassium permanganate, in the water over the apex of the cone; the color shows the movement of the water; it seems to shoot straight up and then to spread itself horizontally at the surface all around; finally, dipping down at the periphery of the tank to form a kind of vertical eddy. This contrivance is thoroughly satisfactory for a small plant, but it would be impracticable for large installations, on account of the cost of construction.

Figure 10 plate I represents the same principles applied by the author to the preliminary clarification of the water on a large scale. It is the outcome of the study which precedes.

Ridges of slates are substituted for conical baffles; they are laid at a slight angle, each row in a contrary way, so as to compel the water to flow in some sort of spiral direction. In this device, as in figure 9, the water flows upward and the sediment is deposited on the upper surface of the slates. In order to maintain these slates or baffles at suitable distances from one another, materials which we will call "impedimentors," varying in size from 1 inch to 2 inches, are placed between them. Each piece of this material acts in the same manner as the slate; as the water flows upward eddies are formed on the surface of each impedimentor, which then becomes a part of the depositing ground for the mud.

In the Lower Roxborough preliminary filters the slates have been omitted. The impeding materials used in the upper layers are somewhat smaller: the smallest varying from $\frac{3}{4}$ inch to 1 inch. This, however, is still big enough to act according to the principle which the author has been trying to explain, wherein the action is one of subsidence in motion, characterized by eddy formation, and not one of true filtration.

To remove the mud which accumulates on the coarse impedimentors two operations are resorted to: one, that of simple flushing by opening a large valve at the bottom of the bed; in this operation the somewhat rapid downflow of the water carries away a portion of the mud; the other, directing a jet of water vertically down on these impedimentors, when, of course, the elastic layer is removed. The latter operation, by pouring a large quantity of water in one particular spot at one time, forces nearly all of the mud, accumulated on the surface of the impedimentors at that particular place, to go down the drain; the jet is systematically applied by hand all over the bed.

As you have seen, there is on the top of the slag an elastic layer made up of sponge. This material has been selected because it is light and therefore easy to handle; because it is porous in the extreme and affords, more than any other substance, room for the mud, and also because it is incapable of decomposition in water. Sponge is, in fact, an ideal natural filter.

In the Lower Roxborough preliminary filters it is practically uncompressed and it affords an extraordinary amount of room for the mud, so that it can work constantly for three, four, and even six months at the rate of 48 to 60 million gallons per acre per day without becoming choked.

Sponge as it comes from the sea contains in its pores a slimy matter called "gurry" which is removed by exposure on the seashore to the alternate action of the tidal waters and to the sun's rays. In this process the "gurry" oozes out, and after a short time nothing but the skeleton is left and the sponge is said to be "cured." This skeleton, which is composed of silica, lime, potash, iodine, and other minerals, is an intricate mass of horny elastic threads—a network permeated by numberless tubes which can be reduced to two systems, one leading from the interior outwardly, and the other from the external surface toward the interior.

Other elastic materials, such as peaty fiber, excelsior, etc., may be used for the same purpose, but the amount of work done by these substitutes or the facility of cleaning is not so great as is the case with sponge, which is the ideal material for the purpose in view—namely, to act as porous impedimentors in the way of the flowing water.

There is an old saying in Germany, that "when water has run over nine stones it has cleared itself." The particles of suspended matter adhere to the surfaces of the stones with which they come in contact. This is often seen in shallow creeks which pass through villages. The

adhesive action whereby the small particles of dirt in the water hang on to the big pieces of filtering or obstructing materials, of course, prevails to a great extent in the Lower Roxborough preliminary filters, both in connection with the slag and the sponge, but we maintain that the influence of this adhesive principle is small as compared with the *subsiding* action to which we have given so much attention.

An exhaustive inquiry was made in 1901 and 1902, by Messrs. Hering and Fuller, into the practicability of the preliminary filters or scrubbers, now under consideration, to aid in solving economically the problem of purifying the Philadelphia water-supply by the slow sand system. A report entitled, "Report on the Investigations made at Philadelphia into the Maignen System of Water Purification for Municipal Supplies, by Rudolph Hering and George W. Fuller, May 3, 1903," was made upon the operation of the scrubbers at our Philadelphia experimental station and at the city testing station at Spring Garden. The following extracts from this report may not be without interest.

"*Does a scrubber allow a final filter to be operated at a higher rate than when the preparatory treatment is obtained by settling basins alone?*

"Regarding the relative fitness for final filtration of a settled water (for, say, one to three days) and a scrubber effluent, it is to be remembered that the greater clearness of the latter is not the only difference. The scrubber effluent is purer from a bacterial standpoint, as the percentage removal of bacteria in the river-water by sedimentation and by scrubbing is about 40 and 80 respectively on an average. Thus, the purity of the scrubber effluent would be three times as great as that of the settled water." [Twenty per cent. of the bacteria are left in the water from the scrubber instead of 60 per cent. left in the water from the settling basin.]

"In a number of places it has been found that when a water has been filtered once, under ordinary conditions as to rate and materials of filtration, a second filtration is sometimes of very little or no benefit. The reason assigned for this experience is that the first filtration removes those constituents which are necessary in order to ripen a filter, through the establishment of gelatinous films around the sand grains, and of certain biological processes.

"This aspect of the matter has received very careful attention, and the evidence shows that excellent results may be regularly obtained from the filtration of the Philadelphia water after it has passed through a scrubber. The construction of the latter and its rate of filtration do not seem to impoverish the local water prejudicially as to those con-

stituents needful for developing and maintaining the final filter in a well ripened and efficient condition.

"Having ascertained that the scrubber effluent in no way lessens the efficiency of final filtration, the question can now be taken up as to whether it allows the final step in the complete process of purification to be carried on at a higher rate than in the case of settled water. The evidence at hand indicates that this is so, and, should there arise any disturbing factors, the effect of such would be less marked with the scrubber effluent, which of itself represents a substantial purification of the river-water. In short, the application of a scrubber effluent of the character noted would insure a greater degree of stability to the final filters, other conditions being the same.

"From the above statement it logically follows that with a scrubber effluent the same degree of stability would be obtained at a higher rate of filtration than in the case of settled water. In practice we certainly believe that this would be true.

"*Does a scrubber prepare the raw water so as to allow the final filter to be operated more cheaply than when settling basins are used?*

"Experience shows that as a general proposition the cost of operating large filter plants of the type under consideration is proportional to the amount of clogged material removed per unit volume of water treated. This statement assumes, of course, comparable conditions as to facilities and wages of laborers, and disregards such special features as removal of ice from open filters. The cost of executive and laboratory control is also excluded, as this is not directly related to the character of the water after it has been prepared for final filtration.

"Experience at several places also shows that, approximately speaking, the amount of clogged material to be removed from filters, other things being equal, is proportional to the turbidity (within ordinary limits) of the applied water.

"When raw water is applied to filters, complications arise in some instances from algæ growth and suspended organic (amorphous) matter, which clogs a filter to an excessive degree in proportion to its turbidity. Notwithstanding the obscuring of data by a variety of causes in practice, this principle is a correct one. From the foregoing it follows that the cost of filter operation is approximately proportional to the turbidity of the applied water, and upon this principle rests one of the principal merits of the scrubber.

"Available evidence indicates that settled water at Philadelphia

would average about 20 parts of turbidity. With filters operated at a 6 million gallon rate and a 4-foot loss of head, the yields between cleanings would probably average about 70 million gallons per acre, and the average depth of scraping about three-fourths of an inch. This makes the amount of clogged material to be handled about 1.5 cubic yards per million gallons of water filtered. As to the average turbidity of a scrubber effluent, it would probably be between 5 and 10 parts. We consider that there is every reason to believe that the average filter yield between cleanings would be about twice as great as with settled water, other things being equal: hence it is concluded that a scrubber effluent as compared with settled water would reduce the cost of filter operation by about 50 per cent.

"*How do the costs of preparing the local river-water by settling basins and by scrubbers compare?*

"From the evidence presented up to this time it is to be gathered that a scrubber could give additional stability to a system of purification in which a high rate of filtration is employed; it is entitled to certain financial credit by making feasible those relatively high rates of filtration; and it could reduce by about 50 per cent. the cost of filter operation. . . .

"*Preparation for filtration of Philadelphia river-water in settling basins.*

"When water approaches quiescence the matters suspended in it are to a greater or lesser degree deposited. The rate of deposition depends upon the remaining velocity of the water in connection with the subsiding value of the suspended particles. Velocities are affected by relative temperatures of water and air, and by the degree of baffling which exists in a basin to prevent water from passing from the inlet to outlet, and thus putting a portion of the basins out of service, practically speaking.

"It is customary in practice to refer to the degree of settling as the period corresponding to the duration of flow required in order to fill the basin; such a period is hardly obtained as a matter of fact, as much of the water passes out in less than this time.

"General experience indicates that as a rule it is not economical or advisable to continue plain sedimentation in water purification works to more than about 24 hours. Exceptions of course are to be found where this factor has to be considered with reference to other portions of some works. . . .

"*Preparation for filtration of Philadelphia river-waters with scrubbers.* . . .

"Regarding the best kind of elastic layer to use, it has been found that sponge clippings are somewhat more efficient than peaty fibre. So far as can be ascertained there is available a sufficient quantity of sponge clippings to serve all needs in view. Should prices become excessive for this commodity, peat or similar material might be substituted temporarily. As to the life of sponge clippings in a scrubber there is no evidence of chemical decomposition, owing to the mineral nature of the product. . . .

"As a scrubber, as well as settling basins, would be operated in connection with filters, it is unnecessary to make any extra charge for watchmen, or for executive and laboratory supervision. The valves would need regulating at only infrequent intervals, and ordinarily could be attended to by the men engaged in cleaning the device. . . .

"*Comparison of efficiency and cost of preparatory treatment of settling basins and scrubbers.*

"The available evidence indicates that the average removal of turbidity from the local river-waters by settling basins (twenty-four hours' capacity) and scrubbers would approximate about 30 and 65 respectively. Regarding bacteria these percentages are estimated at 40 and 80 respectively.

"As to the residual turbidity of the treated water, during all ordinary conditions in the river, it is estimated that it would be about 20 and 10 parts, respectively. The probabilities are that a scrubber effluent is much more likely to average less than 10 parts than is a settling basin less than 20 parts. . . ."

The following are some of the conclusions of the report from which we have just made extracts.

". . . The practicability of the higher rate through the sand layer (6 million gallons per acre per day) of the final filter in the Maignen system is accounted for by the better preparation of the water for filtration. This preparation of the water is accomplished chiefly by the scrubbers. . . ."

"Scrubbers as compared with settling basins make higher rates of filtration feasible in the final filters, perhaps double according to the prevailing practice, and therefore effect in the latter a decided reduction in the cost of filter construction."

"Where reservoirs already exist scrubbers will reduce the cost of operating the final filters sufficiently to save their own total cost, in addition to the saving effected by the smaller area of the filters."

"Where reservoirs are not yet built scrubbers will effect a saving of 70 cents per million gallons of water purified, in addition to the saving effected by the smaller area of the filters."

We have already stated in this paper that filters are not clogged in proportion to the quantity of water filtered, but in proportion to the quantity of mud in the water which is filtered. We have cited Messrs. Hering and Fuller on the same subject in relation to the cost of cleaning filters, and we refer to the same subject again because we believe that in future the students and experts in the art of filtration will find it more correct to state results in terms of units of mud than units of water, or, rather, that they will find a coefficient between mud and water.

All water intended to be filtered may practically be considered as a mud solution with different degrees of density or saturation. The mud in the water has lately been mostly represented in terms of parts per million by the silica standard. This standard is considered the most reliable and quickest optical test. It does not, however, give the exact amount by weight of mud in the water.

Mr. R. S. Weston, in his report to the Sewerage and Water Board of New Orleans, 1903, gives the turbidity coefficient of the Mississippi River water as 1.08; after seventy-two hours' subsidence this turbidity coefficient becomes 0.76. In other words, when the water drawn direct from the river shows 100 parts by the silica standard it may be presumed that there are 108 parts *by weight* of suspended matter; but when the same water has been allowed to subside in a reservoir, the heaviest and bulkiest particles of suspended matter fall to the bottom, and what is left for measurement by the silica standard is extremely fine (and yet sufficient to obscure the light), and then the 100 parts of turbidity by the silica standard is equivalent to only 76 parts *by weight* of suspended matter.

It will be observed, then, that there is quite a large field open for investigation, tabulations, and formulæ to indicate the density of the mud solutions of river-waters intended for purification by filtration.

To ascertain in a rough and ready manner the amount of work done by the Lower Roxborough preliminary filters and to compare it with that of downward sand filters, we have taken a certain quantity of sponge out of a scrubber and weighed it before and after washing. The differences gave the weight of mud retained by the sponge. As a further test we have filtered the muddy wash-water through a paper filter and weighed the residue; this has given the same result as the difference between the sponge, dirty and clean.

We have operated in the same way with dirty sand taken from the top of a plain slow sand filter. It was weighed before and after washing and the wash-water was filtered and the mud collected and weighed. We then found that 1 pound of sponge had retained 5 pounds of mud, while 1 pound of sand had retained only $\frac{1}{32}$ of a pound. In other words, a given quantity of sponge collects in its pores 160 times more mud than the same quantity of sand.

It might be said here that neither the sponge nor the sand was dirty to saturation; both samples were taken from actual filters just put out of service, and it might be said that if allowed to remain longer in service both the sponge and the sand would have collected more mud, but it is presumable that the proportions would be the same at any stage of saturation.

The slag or coke layer which composes the lower part of the preliminary filters has a mud-storing capacity much greater still than the sponge layer, and thus can be explained the fact that these preliminary filters or scrubbers can go on working for four months or more at the rate of 48 million gallons per acre per day without being choked, while a plain slow sand filter bed usually gets clogged after thirty days, working at the rate of 2 million gallons per acre per day, and a mechanical filter after eight hours, working at the rate of 120 million gallons per acre per day.

The amount of mud collected by the preliminary filter averages 65 per cent., but to be conservative we shall say 60 per cent.

The capacity of plain slow sand filters for removing turbidity has been found at Washington, in experiments carried on by Colonel A. M. Miller, to amount to 80 per cent. (See letter from the Secretary of War to Congress, entitled "Feasibility and Propriety of Filtering the Water Supply of Washington, D. C.," March 31, 1900, pages 41 and 42.) In Philadelphia, in practice, at the Roxborough filter plants, it has been found to reach fully 97 per cent., and for the purpose of our illustration we will suppose that the plain slow sand filter can remove the latter quantity.

The yearly average turbidity of the Schuylkill raw river-water is 85 parts by the silica standard. In the winter months the removal of turbidity by twenty-four hours' sedimentation appears to be 20 per cent., and in the summer months about 40 per cent., making an average of 30 per cent. for the whole year. The estimated removal of turbidity by reservoirs is not strictly accurate, on account of the mixing of the first water of a freshet with the clear water of the reser-

voir, but the above estimate may be taken as correct for all practical purposes. The Schuylkill water, therefore, may be estimated to contain, when leaving the sedimentation reservoirs: $85 - 85 \times \frac{30}{100} = 59.5$ parts—say 60 parts—of turbidity by the silica standard.

One million gallons of Schuylkill water coming out of the reservoir would therefore contain 1 million gallons multiplied by 60 parts (gallons) = 60 gallons of mud. There are 7.48 gallons in a cubic foot. The number of cubic feet of mud in a million gallons of water is, therefore, $\frac{60}{7.48} = 8$ cubic feet.

Mr. R. S. Weston, in his report to the New Orleans Sewerage and Water Board (page 101), states that a cubic foot of dry mud weighs 81 pounds. A million gallons of settled Schuylkill water would therefore contain 8 multiplied by 81 = 648 pounds of dry mud.

Preliminary filters cost at the outside $7,000 per million gallons daily capacity. Counting 5 per cent. for interest and depreciation, this gives, $\$7,000 \times \frac{5}{100} = \$350$ per annum, or 1 million gallons multiplied by $\frac{\$350}{365} = 96$ cents per million gallons scrubbed. This is a fixed charge for the preliminary filtration of the water.

At Lower Roxborough the cost of operation and maintenance of the preliminary filter is estimated at 75 cents per million gallons. The *total cost* of treating the water by this preliminary process is therefore:

| | |
|---|---|
| Fixed charges, | 0.96 |
| Operation, | 0.75 |
| Total, | $1.71 per million gallons of water scrubbed. |

One acre of plain slow sand filter costs anywhere between $100,000 and $250,000. For the purpose of this illustration we will take $125,000 per acre as the correct price. The yield of plain slow sand filters, according to the latest estimates made by experts, is 2.22 million gallons per acre per day. The cost of plain slow sand filters can therefore be estimated at $\frac{\$125,000}{2.22} = \$56,000$ per million gallons daily capacity.

The interest and depreciation at 5 per cent. on $56,00 = $2,800 per annum. This gives $\frac{\$2,800}{365} = \$7.67$ per million gallons filtered, as a fixed charge.

The cost of operating plain slow sand filters is variously estimated at from $3.00 to $5.00 per million gallons; $4.00 appears to be the more nearly correct estimate. The total cost of filtering 1,000,000 gallons of water by the plain slow sand filter alone would therefore be:

| | |
|---|---|
| Interest and depreciation, | $7.67 |
| Operation, | 4.00 |
| Total, | $11.67 per m illion gallons of water filtered |

We have seen that to treat 1,000,000 gallons through the scrubber costs $1.71. With a plant dealing with 20 million gallons of water daily, the annual cost, including fixed charges and operation, would therefore be: 20 million gallons multiplied by 365 days at $1.71 = $12,483 per annum.

The water is supposed to contain 60 parts of suspended matter per million gallons, or 648 pounds. Twenty million gallons of water would therefore contain: 20 multiplied by 365 days multiplied by 648 pounds = 4,720,000 pounds or 2,360 tons of mud per annum. The scrubber removes 60 per cent. of this, or $2,360 \times \frac{60}{100} = 1,416$ tons, per annum.

If 1,416 tons of mud, retained by the scrubber during the year, cost $12,483, one ton of mud will cost $\frac{\$12,483}{1,416} = \$8.80$.

We have also seen that a million gallons of water filtered by the plain slow sand filters costs $11.67. Twenty million gallons of water daily will therefore cost 20 multiplied by 365 at $11.67 = $85,191 per annum.

Assuming that 97 per cent. of the mud is removed by the plain slow sand filters, we shall have 2,360 tons $\times \frac{97}{100} = 2,289$ tons per annum. If 2,289 tons of mud, retained by the plain slow sand filter, costs $85,191, one ton of mud will cost $\frac{\$85,191}{2,289} = \$37.66$. It is therefore clear that by dividing the process of purification into two parts—scrubbing and filtering—a considerable economy will be obtained, which, based upon units of mud, can be represented as follows: Single filtration by plain slow sand filters: 97 per cent. of 2,360 tons = 2,289 tons, which at $37.66 = per annum. . .$85,191.00

If the water is first passed through the scrubber, 60 per cent. of the mud will be removed; 60 per cent. of 2,360 tons = 1,416 tons at $8.80 = $12,483

The mud left for the final slow sand filter to remove amounts to 40 per cent., of 2,360 tons = 1,416 tons = 944 tons.

The plain slow sand filter will remove 97 per cent. of 944 tons, at a cost of $37.66 per ton = 35,551 48,034.00

$37,157.00

This represents an economy of $37,157.00 per annum for a filter plant dealing with twenty million gallons of river-water daily, of the character of the Schuylkill.

## Some Details of Construction and Operation.

The topography of the ground adjacent to the sand filter beds at Lower Roxborough made it necessary to construct an embankment of earth, averaging 12 feet in height, for the erection of the preliminary filters. The micaceous soil of the locality was used and was rolled in layers of 6 inches with a 10-ton steam-roller. Twelve inches of puddle was placed all over the surface.

It is usual, when building concrete work on made ground, to allow a certain time, preferably a winter, to pass before building, in order

Fig. 4.—Scrubber House During Construction.

to allow the ground to settle; when this time cannot be secured, it is good practice to strengthen the concrete by expanded metal or its equivalent. The embankment for the Lower Roxborough preliminary filters was so carefully made that it was considered feasible to lay the concrete on the ground as soon as the puddle was in place; and no special measures were taken against settlement. It was assumed that the small settlement that might take place would be uniform and therefore not likely to affect the concrete of the filter tanks. As a matter of fact, there have been no settling breaks in the walls or

in the floors. There have been three contraction cracks, but these were slight and they were easily repaired.

The floors and the walls are made of plain concrete, with the exception of the base of the walls, which has been anchored in the floor by means of ½-inch square rods 18 inches long, placed vertically every 12 inches, and also some 1-inch square rods 4 feet 6 inches and 6 feet long, laid horizontally every 6-inch center, in that part of the floor which serves as a base for the walls.

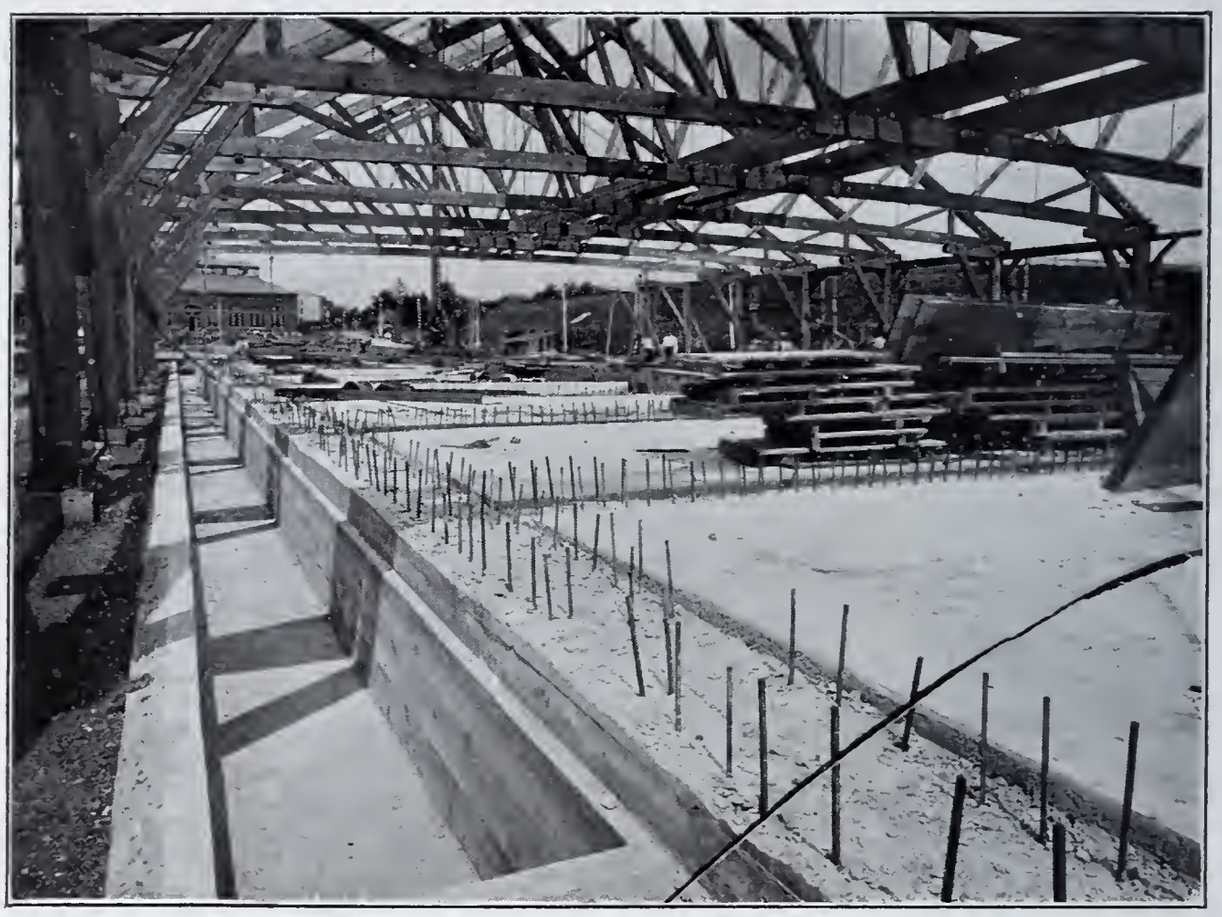

Fig. 5.—Floor and Gullet of Scrubbers, Showing Reinforcement for Walls.

The division walls are 15 inches at the top and 24 inches at the bottom. The outer walls are also 15 inches at the top, but 30 inches at the base. The total height of the tanks is 6 feet. The floor itself is dished, being 14 inches thick at the wall and 6 inches thick in the center. Bolts 1 inch in diameter are inserted in the walls to secure in place the 15-inch I-beams which are intended to resist the upward thrust of the elastic layer.

There are altogether 11 tanks, 16 feet wide and 64 feet long, giving 1024 square feet of filtering area for each tank, or 11,264 square feet

for the 11 units. The whole plant is designed to scrub 12 million gallons of water every twenty-four hours.

When all the units are at work, the rate of filtration is 0.74 gallons per square foot per minute; or 1065 gallons per square foot per day; or 46,417,436 gallons per acre per day. When one filter is out of service and the full 12 million gallons are wanted, the rate of filtration is increased to 0.81 gallons per square foot per minute; or 1164 gallons per square foot per day; or 50,808,384 gallons per acre per day. The latter rate is by no means excessive; in fact, the filters may be rated

Fig. 6.—Division and Outer Walls Showing Opening for Weir.

at 60 million gallons per acre per day, which is equivalent to 0.956 gallons per square foot per minute. If the 11 filters were at work at this rate, they would give 15,506,467 gallons per twenty-four hours. Although this may be accounted the maximum capacity of the Lower Roxborough preliminary filters, they might, in an emergency, work without any damage up to an 80- or 90-million gallon rate.

The water supplied to the Lower Roxborough Filter Station is drawn from the Schuylkill at the Shawmont Pumping Station. It passes through a reservoir containing about 12 million gallons, which

is equivalent to twenty-four hours' supply. When full, the highest elevation of the water in the reservoir is 366.0 feet C. D. It flows by gravity through a 24-inch pipe into the preliminary filters the top of which is at elevation 350.5 feet C. D.

On the north or influent side of the house the 24-inch supply-pipe, which crosses over the filters in the middle of the building, is connected with a 24-inch by 18-inch by 18-inch tee to two lines of influent pipes gradually reduced in size, right and left, the whole length of the

Fig. 7.—Lower Roxborough Preliminary Filter House.

bed. On this line are placed tees with a 6-inch branch leading to a 6-inch gate valve with indicator. Beyond the valve is a reducer 6 to 8-inch and an 8-inch butterfly valve connected to an 8-inch cast-iron pipe which goes through the wall at the bottom of the filter. This pipe enters a small brick chamber, inside of the bed, which acts as an air-chamber, and out of which the air that escapes from the influent water finds an exit through a 1-inch brass pipe communicating with the air. From the brick chamber starts an 8-inch terra-cotta tee with two 8-inch to 6-inch reducers and ells leading to two lines of

perforated terra-cotta pipe, running the full length of the bed; these pipes are laid with cement joints and are seen in figure 8.

In the center of the bed is a line of special drain tiles made of concrete and expanded metal. The concrete is 3 inches thick, 3 feet wide, and 6 inches high (inside measurements); the tiles are made in pieces 6 feet long.

The wash-water passes through openings 4 inches by 2 inches at the sides of the tiles and immediately over the floor, which acts as the bottom of the drain. The floor has a fall of 1 inch in its total

Fig. 8.—Distributing and Draining Systems.

length. An opening in the floor, at the front end, leads to a 16-inch gate valve, which is opened when flushing is necessary.

On the south side of the filters is a weir, over which the filtered or scrubbed water flows. It is 22.5 inches wide and has a sharp brass crest. A glass gauge connected with a brass pipe, which goes through the wall, indicates the height of water flowing over the weir. A similar gauge going through the back wall assists the filter attendant in regulating properly the 6-inch influent valves.

From the weirs the water falls into galvanized iron boxes having

two outlets at the bottom, one with a 6-inch waste valve, to let the scrubbed water go into the wash-out gullet if it should not be good enough to go to the final filters, and an 8-inch outlet with valve, connecting with the general effluent pipe, which takes the filtered water from all of the 11 units and conveys it to the final filters.

Another glass gauge, attached to a brass pipe leading to the bottom of the filter bed, shows the resistance offered by the sponge layer. The difference between the level of the water in this influent gauge and the level of the water in the effluent or weir gauge is the loss of head, and indicates the frictional resistance occurring in the filtering materials. When the filter is freshly cleaned there is practically no loss of head at all, but as the operation continues it gradually increases to one and a half feet; when it has reached this latter figure, it is considered time to clean.

The sponge layer is held down by cedar slats bound together three by three with battens, so as to form boards about 10 inches wide; these slat boards are 15 feet 11 inches long and weigh about 40 pounds each, and they are easily handled by one or two men; these are in turn held in place by four lines of yellow pine stringers, 6 inches by 8 inches, running along the whole length of the bed. These stringers are pressed down a few inches by means of screw-jacks and are held in position by yellow pine blocks placed under the steel I-beams above.

## Cleaning.

When cleaning becomes necessary, and this happens twice a year, one filter unit at a time is put out of service. Men with brooms clean the slats before the water is drawn off. The 16-inch flushing valve is opened and the filter is drained. The sponge is then taken from the bed and placed in tin-lined wicker baskets; these baskets are hoisted above the level of the I-beams and conveyed to the washing machines by means of a tram-rail overhead conveyor. The sponge is brought back in the same manner, after being cleaned.

After the sponge has been removed from a section of the bed the slag or coke is washed in place by means of a hose which is carried by hand all over the bed. During this operation there is no other water in the filter, so that the wash-water, which is brought to bear in one place in large volume and with force, drives the mud down easily and it escapes freely by the 16-inch wash valve. The appearance of this very muddy wash-water is one of the evidences of the efficacy of this kind of washing and of the mud-catching properties of the device.

When all the sponge of a bed has been cleaned and replaced, the filter is filled with water; then the 16-inch valve is opened full and any mud that may still remain in the materials of the bed, is easily carried away to the drain by this flushing, which is repeated twice. The cleaning of the materials is so complete that when the filters are restarted there is no initial loss of head whatever.

The sponge-washing machinery consists of a battery of four regular laundry cylinder washers worked by a 10 h. p. electric motor. These washers consist of an outer drum and an inner one. The inner drum

Fig. 9.—Replacing the Sponge in the Scrubber.

is perforated and turns in water, first in one direction then in another, shaking the sponges in water and extracting the mud without tearing them. The sponges are left in the first water one minute, then in a second water two or three minutes, in a third water three or four minutes, and so on for five changes, the whole operation taking half an hour for completion. The sponges of one bed can be washed in three days, but as it is necessary to wash the impedimentors (slag or coke), and also to remove, wash, and replace the slats and stringers, the entire operation takes four and a half days.

From present evidence it is believed that not more than two or three cleanings will be necessary each year. Each unit will therefore be out of service not more than fifteen days in one year and at work three hundred and fifty days. It can be easily understood that a machine which is made to wash lace curtains can wash dirty sponges without tearing them. There is practically no waste of sponge whatever either in use or in the *cleaning operation.*

The quantity of water used to wash one bed does not amount to

Fig. 10.—Sponge-washing Machinery.

more than 200,000 gallons, or about one-tenth of one per cent. of the water filtered.

The raw water, without any pressure, is used for flushing and for sponge washing; raw water may be used also for the hose, but it should be delivered under pressure. Five men are necessary for the cleaning operation, one to fill the baskets with dirty sponge and distribute the clean sponge, one to convey the baskets to and from the washing machines, two to fill and empty the washing cylinders, and one to look after the motor and the valves of the washing machines.

## Results Obtained.

Eight of the eleven filter tanks or scrubbers were started on October 27, 1903; the other three were kept under test for water-tightness, owing to small contraction cracks which occurred in the outer walls. These last filters were put in service on the 6th and 7th of January, 1904.

The quantity of water filtered by the whole plant has varied from 6 to 12 million gallons per day, according to the requirements of the consumers and the capacity of the Shawmont Pumping Station. The highest consumption occurred during the coldest weather and at a time when the water was at its worst in turbidity and bacteria.

The scrubbers were set to work at 48 million gallons per acre per day. When less than 12 million gallons were required, two or three units were lowered in speed to suit the requirements of the final filters, the majority of the scrubbers being allowed to remain at the normal rate. Sometimes when a sudden demand for filtered water in town or a break in the distribution system occurred, it was found necessary to raise the rate of filtration in the scrubbers to 60, 80, and 100 million gallons per acre per day. This variation in rates is a very severe test for any kind of filter. No unsatisfactory results, however, followed these great variations, and in fact no difference whatever has been noticed analytically in the quality of the filtrate at any time, that could be traced to a change in the rate of filtration.

The following results may be taken as representing the minimum efficacy of the plant. The filtering materials—that is, the slag or coke and the sponge—were placed originally in the tanks by common laborers without any special care; now the sponge, after cleaning, is replaced in the scrubbers by a man who has acquired the necessary experience to insure that the layer will be even all over the bed, particular care being taken to insure a good layer at the edges against the walls, so that the results in the future may be expected to be better than those of the past.

TABLE SHOWING THE RESULTS OF TURBIDITY AND BACTERIOLOGICAL EXAMINATIONS AT THE PRELIMINARY FILTERS, LOWER ROXBOROUGH, PHILADELPHIA.*

| Date. | River Water. | | Reservoir Water. | | General Effluent of Scrubbers. | | | |
|---|---|---|---|---|---|---|---|---|
| | Turbidity. | Bacteria. | Turbidity. | Bacteria. | Turbidity. | Per cent. removed. | Bacteria. | Per cent. removed. |
| 1903. | | | | | | | | |
| Dec. 23 . . . . | 130 | No samples | 65 | No samples | 26 | 60 | No samples | |
| " 24 . . . . | 130 | | 85 | | 28 | 67 | | |
| " 25 . . . . | | | | | | | | |
| " 26 . . . . | 80 | | 80 | | 18 | 78 | | |
| Weekly Average | 113 | | 77 | | 24 | 69 | | |
| Dec. 28 . . . . | 20 | No samples | 20 | No samples | | | No samples | |
| " 29 . . . . | 15 | | 18 | | | | | |
| " 30 . . . . | | | 15 | | 8 | 47 | | |
| " 31 . . . . | 14 | | 14 | | 5 | 64 | | |
| 1904. | | | | | | | | |
| Jan. 2 . . . . | | | 14 | | 3 | 79 | | |
| Weekly Average | | | | | | | | |
| Jan. 4 . . . . | 6 | 192,000 | 7 | 20,000 | 2 | 71 | 1,700 | 92 |
| " 5 . . . . | 4 | 62,000 | 4 | 4,400 | 2 | 50 | No samples | |
| " 6 . . . . | 3 | 63,000 | 4 | 90,000 | 2 | 50 | | |
| " 7 . . . . | 3 | 32,000 | 4 | 68,000 | 2 | 50 | 12,800 | 81 |
| " 8 . . . . | 4 | † | 4 | † | 2 | 50 | † | |
| " 9 . . . . | 4 | 29,500 | 4 | 25,500 | 2 | 50 | 6,800 | 74 |
| Weekly Average | 4 | 84,000 | 4 | 38,000 | 2 | 50 | 7,100 | 81 |
| Jan. 11 . . . . | 3 | 32,500 | 4 | 64,000 | 1 | 75 | 3,500 | 95 |
| " 12 . . . . | 4 | 6,800 | 4 | 33,500 | 2 | 50 | 2,700 | 92 |
| " 13 . . . . | 4 | 2,900 | 4 | 10,500 | 2 | 50 | 1,500 | 86 |
| " 14 . . . . | 20 | 30,000 | 7 | 15,000 | 2 | 71 | 1,100 | 93 |
| " 15 . . . . | 20 | † | 15 | † | 5 | 66 | † | |
| " 16 . . . . | 14 | 15,500 | 15 | 14,500 | 6 | 60 | 4,700 | 67 |
| Weekly Average | 11 | 17,500 | 8 | 27,500 | 3 | 62 | 2,700 | 90 |
| Jan. 18 . . . . | 14 | 8,600 | 14 | 23,000 | 4 | 71 | 950 | 96 |
| " 19 . . . . | 9 | 43,500 | 9 | 112,000 | 4 | 55 | 17,500 | 84 |
| " 20 . . . . | 5 | 43,500 | 8 | 99,000 | 3 | 62 | 15,500 | 85 |

* Results obtained by D. M. Belcher, Bacteriologist in the Maignen Laboratory.

† Seventy-two hours incubation, results not recorded.

RESULTS OF TURBIDITY AND BACTERIOLOGICAL EXAMINATIONS.—*Continued.*

| Date. | River Water. | | Reservoir Water. | | General Effluent of Scrubbers. | | | |
|---|---|---|---|---|---|---|---|---|
| | Turbidity. | Bacteria. | Turbidity. | Bacteria. | Turbidity. | Per cent. removed. | Bacteria. | Per cent. removed. |
| 1904. | | | | | | | | |
| Jan. 21 . . . . | 5 | 30,500 | 5 | 68,000 | 3 | 40 | 19,500 | 71 |
| " 22 . . . . | 6 | * | 5 | * | 3 | 40 | * | |
| " 23 . . . . | 250 | 124,000 | 96 | 33,000 | 20 | 79 | 5,500 | 83 |
| Weekly Average | 48 | 50,000 | 23 | 67,000 | 6 | 74 | 11,800 | 82 |
| Jan. 25 . . . . | 180 | 85,000 | 160 | 163,000 | 65 | 59 | 66,000 | 59 |
| " 26 . . . . | 110 | 113,000 | 96 | 150,000 | 48 | 50 | 48,000 | 68 |
| " 27 . . . . | 90 | 31,000 | 96 | 220,000 | 44 | 54 | 58,000 | 74 |
| " 28 . . . . | 55 | 96.000 | 64 | 160,000 | 32 | 50 | 73,000 | 55 |
| " 29 . . . . | 20 | * | 36 | * | 15 | 58 | * | |
| " 30 . . . . | 15 | 21,500 | 20 | 42,500 | 6 | 70 | 8,300 | 80 |
| Weekly Average | 78 | 69,000 | 79 | 150,000 | 35 | 56 | 50,000 | 67 |
| Average for Month of Jan. | 35 | 52,000 | 28 | 74,000 | 11 | 61 | 19,000 | 74 |
| Feb. 1 . . . . | 4 | 150,000 | 8 | 240,000 | 3 | 62 | 58,000 | 76 |
| " 2 . . . . | 4 | 89,000 | 8 | 125,000 | 2 | 75 | 19,000 | 85 |
| " 3 . . . . | 5 | 105,000 | 8 | 170,000 | 2 | 75 | 33,000 | 81 |
| " 4 . . . . | 4 | 160,000 | 5 | 220,000 | 1 | 80 | 35,500 | 84 |
| " 5 . . . . | 4 | 80,000 | 5 | 240,000 | 1 | 80 | 32,000 | 87 |
| " 6 . . . . | No sample | | 4 | 130,000 | 1 | 75 | 17,500 | 87 |
| Weekly Average | 4 | 120,000 | 6 | 190,000 | 2 | 67 | 32,500 | 83 |
| Feb. 8 . . . . | 130 | 65,000 | 20 | 35,000 | 3 | 85 | 6,000 | 83 |
| " 9 . . . . | 55 | 130,000 | 55 | 200,000 | 15 | 73 | No sample | |
| " 10 . . . . | 32 | 240,000 | 55 | 530,000 | 15 | 73 | 120,000 | 77 |
| " 11 . . . | 12 | 210,000 | 26 | 450,000 | 10 | 62 | No sample | |
| " 12 . . . . | 12 | No sample | 15 | No sample | 3 | 80 | | |
| " 13 . . . . | 8 | 110,000 | 10 | 180,000 | 3 | 70 | 30,000 | 83 |
| Weekly Average | 41 | 140,000 | 30 | 250,000 | 8 | 73 | 52,000 | 79 |
| Feb. 15 . . . . | 4 | 14,000 | 5 | 21,500 | 1 | 80 | 3,700 | 83 |
| " 16 . . . . | 6 | 11,500 | 6 | 19,000 | 1 | 83 | 3,500 | 82 |
| " 17 . . . . | 6 | 10,000 | 5 | 27,000 | 2 | 60 | 4,200 | 85 |
| " 18 . . . . | 4 | 8,500 | 4 | 36,000 | 2 | 50 | 4,800 | 87 |

*Seventy-two hours incubation, results not recorded.

RESULTS OF TURBIDITY AND BACTERIOLOGICAL EXAMINATIONS.—*Continued.*

| Date. | River Water. | | Reservoir Water. | | General Effluent of Scrubbers. | | | |
|---|---|---|---|---|---|---|---|---|
| | Turbidity. | Bacteria. | Turbidity. | Bacteria. | Turbidity. | Per cent. removed. | Bacteria. | Per cent. removed. |
| 1904. | | | | | | | | |
| Feb. 19 . . . . | 5 | 14,500 | 5 | 28,000 | 1 | 80 | 3,300 | 88 |
| " 20 . . . . | 5 | 11,000 | 4 | 44,500 | 1 | 75 | 5,500 | 88 |
| Weekly Average | 5 | 11,500 | 5 | 29,500 | 1 | 80 | 4,200 | 86 |
| Feb. 22 . . . . | 680 | 95,000 | 48 | 150,000 | 6 | 88 | 21,000 | 86 |
| " 23 . . . . | 320 | 180,000 | 200 | 300,000 | 70 | 65 | 67,000 | 78 |
| " 24 . . . . | 250 | 90,000 | 250 | 240,000 | 96 | 62 | 28,000 | 88 |
| " 25 . . . . | 160 | 60,000 | 190 | 160,000 | 80 | 58 | 15,000 | 91 |
| " 26 . . . . | 86 | 61,000 | 100 | 260,000 | 48 | 52 | 150,000 | 42 |
| " 27 . . . . | 96 | 51,000 | 86 | 74,000 | 32 | 63 | 30,000 | 60 |
| Weekly Average | 265 | 90,000 | 146 | 200,000 | 55 | 62 | 52,000 | 74 |
| Feb. 29 . . . . | 120 | 280,000 | 80 | 440,000 | 20 | 75 | No sample | |
| Average for Month of Feb. | 84 | 90,000 | 48 | 170,000 | 16 | 67 | 35,000 | 79 |
| Feb. 29 . . . . | 120 | 280,000 | 80 | 440,000 | 20 | 75 | No sample | |
| March 1 . . . | 170 | 90,000 | 86 | 250,000 | 25 | 71 | 75,000 | 70 |
| " 2 . . . | 200 | 280,000 | 120 | 430,000 | 38 | 68 | 110,000 | 74 |
| " 3 . . . | 150 | 240.000 | 130 | 290,000 | 40 | 69 | 130,000 | 55 |
| " 4 . . . | 150 | 45,000 | 120 | 95,000 | 40 | 67 | 45,000 | 53 |
| " 5 . . . | 250 | 65,000 | 150 | 65,000 | 50 | 66 | 21,500 | 67 |
| Weekly Average | 175 | 140,000 | 114 | 230,000 | 35 | 69 | 76,000 | 67 |
| March 7 . . . | 250 | 100,000 | 280 | 250,000 | 100 | 64 | 88,000 | 65 |
| " 8 . . . | 1500 | 200,000 | 750 | 180,000 | 320 | 57 | 49,000 | 73 |
| " 9* . . | 1200 | No sample | 1000 | 170,000 | 550 | 45 | 78,000 | 54 |
| " 10* . . | 320 | 50,000 | 600 | 60,000 | 340 | 43 | 29,000 | 52 |
| " 11* . . | 160 | 15,000 | 320 | 40,000 | 175 | 45 | 14,000 | 65 |
| " 12* . . | 110 | No sample | 160 | No sample | 85 | 47 | No sample | |
| Weekly Average | 590 | 110,000 | 520 | 140,000 | 260 | 50 | 50,000 | 64 |
| March 14* . . | 80 | 13,000 | 55 | 19,000 | 28 | 49 | 7,500 | 61 |
| " 15 . . . | 28 | 4,000 | 38 | 12,000 | 16 | 58 | 4,500 | 62 |
| " 16 . . . | 38 | 2,000 | 32 | 9,000 | 16 | 50 | 1,800 | 80 |

* Disturbance occurred owing to cleaning some of the scrubbers and sudden changes of rate in others.

RESULTS OF TURBIDITY AND BACTERIOLOGICAL EXAMINATIONS.—*Continued.*

| Date. | River Water. | | Reservoir Water. | | General Effluent of Scrubbers. | | | |
|---|---|---|---|---|---|---|---|---|
| | Turbidity. | Bacteria. | Turbidity. | Bacteria. | Turbidity. | Per cent. removed. | Bacteria. | Per cent. removed. |
| 1904. | | | | | | | | |
| March 17 . . . | 38 | 31,000 | 38 | 20,000 | 16 | 58 | 5,700 | 71 |
| " 18 . . . | 70 | 14,000 | 32 | 18,500 | 13 | 59 | 5,500 | 70 |
| " 19 . . . | 450 | 26,000 | 125 | 17,000 | 48 | 62 | 7,300 | 57 |
| Weekly Average | 117 | 15,000 | 53 | 16,000 | 23 | 56 | 5,400 | 66 |
| March 21 . . . | 250 | 31,000 | 125 | 21,000 | 50 | 60 | 5,000 | 76 |
| " 22 . . . | 200 | 28,000 | 160 | 21,000 | 75 | 53 | 4,500 | 79 |
| " 23 . . . | 80 | 40,000 | 160 | 30,000 | 70 | 56 | 12,000 | 60 |
| " 24 . . . | 32 | 20,000 | 80 | 46,000 | 48 | 40 | 4,400 | 90 |
| " 25 . . . | 30 | 51,000 | 64 | 63,000 | 30 | 53 | 18,000 | 71 |
| " 26 . . . | 25 | 36,000 | 48 | 42,000 | 16 | 67 | 9,800 | 74 |
| Weekly Average | 103 | 34,500 | 106 | 37,000 | 48 | 55 | 8,900 | 76 |
| March 28 . . . | 15 | 49,000 | 22 | No sample | 10 | 55 | No sample | |
| " 29 . . . | 15 | 37,000 | 17 | 67,000 | 8 | 53 | 14,500 | 78 |
| " 30 . . . | 13 | 25,000 | 15 | 25,000 | 6 | 60 | 6,400 | 74 |
| " 31 . . . | 15 | No sample | 15 | No sample | 6 | 60 | No sample | |
| Average for Month of March. | 216 | 62,000 | 175 | 94,000 | 82 | 53 | 26,500 | 72 |
| March 28 . . . | 15 | 49,000 | 22 | No sample | 10 | 55 | No sample | |
| " 29 . . . | 15 | 37,000 | 17 | 67,000 | 8 | 53 | 14,500 | 78 |
| " 30 . . . | 13 | 25,500 | 15 | 25,000 | 6 | 60 | 6,400 | 74 |
| " 31 . . . | 15 | No samples | 15 | No Samples | 6 | 60 | No samples | |
| April 1 . . . | 13 | | 13 | | 6 | 54 | | |
| " 2 . . . | | | 90 | | 44 | 51 | | |
| Weekly Average | | 31,000 | 29 | 46,000 | 13 | 55 | 10,500 | 77 |
| April 4 . . . | 125 | 28,000 | 160 | 35,000 | 70 | 56 | 7,100 | 80 |
| " 5 . . . | 60 | 8,000 | 120 | 43,000 | 65 | 46 | 12,000 | 72 |
| " 6 . . . | 32 | 4,400 | 90 | 10,000 | 35 | 61 | 2,100 | 79 |
| " 7 . . . | 48 | 9,500 | 55 | 8,500 | 16 | 71 | 1,900 | 78 |
| " 8 . . . | 22 | 30,000 | 50 | 9,500 | 22 | 56 | 2,000 | 79 |
| " 9 . . . | 22 | 14,500 | 38 | 7,700 | 13 | 66 | 2,000 | 74 |
| Weekly Average | 51 | 15,500 | 85 | 19,000 | 37 | 56 | 4,500 | 76 |
| April 11 . . . | 22 | 38,500 | 24 | 10,500 | 10 | 58 | 1,400 | 87 |

RESULTS OF TURBIDITY AND BACTERIOLOGICAL EXAMINATIONS.—*Continued.*

| Date. | River Water. | | Reservoir Water. | | General Effluent of Scrubbers. | | | |
|---|---|---|---|---|---|---|---|---|
| | Turbidity. | Bacteria. | Turbidity. | Bacteria. | Turbidity. | Per cent. removed. | Bacteria. | Per cent. removed. |
| 1904. | | | | | | | | |
| April 12 . . . | 16 | 13,000 | 18 | 6,500 | 8 | 56 | 1,000 | 83 |
| " 13 . . . | 22 | | 17 | | 7 | 59 | | |
| " 14 . . . | 22 | No | 16 | No | 6 | 62 | No | |
| " 15 . . . | | samples | 16 | samples | 5 | 69 | samples | |
| " 16 . . . | | | 22 | | 8 | 64 | | |
| Weekly Average | 20 | 25,000 | 19 | 8,500 | 7 | 63 | 12,000 | 86 |
| April 18 . . . | No sample | | 20 | No sample | 5 | 75 | No sample | |
| " 19 . . . | 13 | 7,500 | 14 | 2,400 | 5 | 64 | 500 | 79 |
| " 20 . . . | 50 | 1,800 | 20 | 1,000 | 5 | 75 | 130 | 87 |
| " 21 . . . | 14 | 7,100 | 25 | 2,800 | 5 | 80 | 400 | 86 |
| " 22 . . . | 6 | 3,800 | 18 | 900 | | | | |
| " 23 . . . | 7 | 3,900 | 16 | 1,900 | | | † | |
| Weekly Average | 29 | 5,500 | 20 | 2,000 | 5 | 75 | 340 | 83 |
| April 25 . . . | 8 | 7,500 | 10 | 4,200 | | | | |
| " 26 . . . | 6 | 13,500 | 8 | 7,200 | | | | |
| " 27 . . . | 7 | 17,500 | 12 | 10,000 | | | | |
| " 28 . . . | 10 | 63,000 | 12 | 16,000 | | | † | |
| " 29 . . . | 8 | No sample | 10 | No sample | | | | |
| " 30 . . . | 10 | 50,000 | 12 | 29,000 | | | | |
| Weekly Average | 8 | 30,500 | 10 | 13,500 | | | | |
| Average for month of April.* | | 14,500 | 45 | 12,500 | 18 | 60 | 2,700 | 78 |
| May 2 . . . . | 12 | 20,000 | 10 | 23,000 | No samples | | | |
| " 3 . . . . | 12 | 30,000 | 11 | 16,000 | 5 | 55 | 6,600 | 59 |
| " 4 . . | 12 | 44,000 | 8 | 18,000 | 3 | 62 | 5,300 | 71 |
| " 5 . . . . | No sample | | 6 | No | 3 | 50 | No samples | |
| " 6 . . . . | taken | | 7 | sample | 3 | 57 | | |
| " 7 . . . . | 11 | 58,000 | 7 | 23,500 | 3 | 57 | 6,800 | 71 |
| Weekly Average | 12 | 44,000 | 8 | 19,000 | 3 | 63 | 6,200 | 67 |
| May 9 . . . . | 11 | 22,000 | 6 | 17,500 | 2 | 66 | 5,100 | 71 |
| " 10 . . . . | 10 | 10,500 | 5 | 13,500 | 1 | 80 | 1,700 | 87 |

† Scrubbers put out of service in order that raw water might be supplied to the plain slow sand filters for experimental purposes.

* Average of part of month during which the Scrubbers were in service.

RESULTS OF TURBIDITY AND BACTERIOLOGICAL EXAMINATIONS.—*Continued.*

| Date. | River Water. | | Reservoir Water. | | General Effluent of Scrubbers. | | | |
|---|---|---|---|---|---|---|---|---|
| | Turbidity. | Bacteria. | Turbidity. | Bacteria. | Turbidity. | Per cent. removed. | Bacteria. | Per cent. removed. |
| 1904. | | | | | | | | |
| May 11 . . . . | 12 | 46,000 | 6 | 9,500 | 1 | 83 | 3,000 | 68 |
| " 12 . . . . | 10 | 53,000 | 6 | 24,500 | 1 | 83 | 3,500 | 86 |
| " 13 . . . . | 14 | 31,500 | 5 | 12,500 | 1 | 80 | 2,700 | 78 |
| " 14 . . . . | 10 | 28,000 | 4 | 13,000 | 1 | 75 | 1,800 | 86 |
| Weekly Average | 11 | 32,000 | 5 | 15,000 | 1 | 80 | 2,900 | 81 |
| May 16 . . . . | 10 | 13,500 | 4 | 6,200 | 1 | 75 | 520 | 92 |
| " 17 . . . . | 5 | 5,000 | 4 | 6,800 | 1 | 75 | 800 | 88 |
| " 18 . . . . | 5 | 12,500 | 4 | 4,300 | 1 | 75 | 700 | 84 |
| " 19 . . . . | 7 | 19,500 | 4 | 16,500 | 1 | 75 | 3,500 | 79 |
| " 20 . . . . | 7 | 34,500 | 4 | 14,000 | 1 | 75 | 2,700 | 81 |
| " 21 . . . . | 7 | 31,000 | 4 | 15,000 | 1 | 75 | 3,000 | 80 |
| Weekly Average | 7 | 19,000 | 4 | 10,500 | 1 | 75 | 1,800 | 83 |
| May 23 . . . . | 4 | 29,000 | 3 | 26,000 | 1 | 66 | 1,600 | 94 |
| " 24 . . . . | 4 | Liq. | 3 | 23,500 | 1 | 66 | 2,200 | 91 |
| " 25 . . . . | 4 | " | 4 | Liq. | 1 | 75 | Liq. | |
| " 26 . . . . | 6 | 34,500 | 5 | 14,000 | 1 | 80 | 4,200 | 70 |
| " 27 . . . . | 4 | 9,700 | 4 | 11,000 | 1 | 75 | No sample | |
| " 28 . . . . | 3 | 27,000 | 4 | 24,000 | 1 | 75 | 1,900 | 92 |
| Weekly Average | 4 | 25,000 | 4 | 22,000 | 1 | 75 | 2,500 | 89 |
| May 30 . . . . | 4 | No sample | 4 | No sample | 1 | 75 | No sample | |
| " 31 . . . . | 60 | 44,000 | 9 | | 1 | 89 | | |
| Average for month of May . | 10 | 29,000 | 5 | 15,500 | 1 | 80 | 3,000 | 81 |

## DISCUSSION.

HENRY LEFFMANN.—In regard to the figures showing relation of bacteria to turbidity, it should be noted, in the first place, that the latter datum is determined by methods which are satisfactory in themselves as a standard, when the tests are numerous and have been carried on for a considerable period; but they do not necessarily have any proper relations to the number of the bacteria. Determining a particular degree of turbidity in comparison with the bacteria may be simply making comparison between two naturally discordant data. The turbidity is determined in this city by the silica-standard, which consists

in distributing through a volume of water known quantities of silica. There are other methods; each is satisfactory when compared with itself, but none is absolute. The degree of turbidity is liable to mis-estimation—if I may be allowed to coin the word—in consequence of the variation of the suspended matters in color and in composition.

Secondly, it must be borne in mind that the whole question of counting bacteria in water is in an unsatisfactory state. In spite of the large amount of work done in this field, the methods are not yet standard or absolute; they are only relative. The methods of culture and many other questions enter into the determination of the absolute number. Moreover, as I understand it, these are mere microbe countings. There is no attempt to differentiate the bacteria. They are cultivated according to a standard method and at standard temperature, and the character of the water varies from day to day. The water may count ten thousand bacteria to the cubic centimeter one day, and twenty thousand the next day, yet both samples may have the same number of bacteria in them, because the viability of the organisms may differ on the two days. One set may grow better than the other. There is no reason to be surprised at the want of coincidence between the figures for bacteria and turbidity. Inferences have been drawn from earlier investigations, but they do not apply to the later period. When water lies in a reservoir subject to sunshine, the temperature rises, and temperature has a very marked effect upon the growth of the bacteria. When water is quite cold, the bacterial growth is feeble. In the case of a small town, in the interior of the State, some years ago, the water commissioners were very anxious to have a bacterial count made of the water from the river and of the effluent of a small coagulation plant put in for purification. I advised them that it would be hardly worth while to make the count at that time, because the bacteria in the river would probably be very low, the weather being very cold. The result was twenty bacteria to the cubic centimeter cultivated in the ordinary methods in the river-water and twenty-two in the filtered water. While this did not mean anything to the bacteriologist, it meant a serious disappointment to the water commissioners. When we deal with enormous numbers we have again sources of serious uncertainty. In reservoirs the water becomes warm and the bacteria grow with great speed, and a count taken after a few hours in this condition will show very high figures. On the other hand, many bacteria are killed by the action of the sunlight, and if the samples are taken from no great depth in the reservoir, the count may be very low because of the sunshine. All these facts must be kept in view in collecting data of this kind. For any series of observations the data are capable of interpretation among themselves, but are not capable of application to other investigations made under different conditions.

Dr. Robin.—I was speaking to Mr. Maignen to-day of the methods which I employ in the bacteriological examination of water and which are along the lines suggested by Dr. Leffmann, namely, that an attempt is made to separate as far as possible saprophytic from pathogenic bacteria by growing the plates at high temperature (38° to 40° C.) and making use of various culture-media. I make use of lactose agar plates which are rendered anaerobic by covering the medium with a layer of agar-jelly; also lactose agar containing 0.1 per cent. of carbolic acid. The comparative counts on gelatin and on the above media give

an inkling as to the character of the bacteria present in the water. So far this differential method has given me satisfactory results.

Wm. R. Copeland.—Our methods of making bacteriological tests upon water may be divided into two classes: by the first series of tests we determine, in a general way, how many bacteria are present in a known volume of the water—for instance, in a cubic centimeter of the water. By the second series of tests we determine whether sewage bacteria—that is to say, bacteria which are common in sewage—are present.

In order to study bacteria it is necessary to bring them under our control. They are very small, and often very active organisms. Should we place them under a microscope, in a drop of water, they would swim out of sight, or several individuals would become tangled together in a mass and make it impossible to distinguish one from another. If, however, a cubic centimeter of the water under observation is placed in a mixture of melted gelatin, beef-juice, and peptone, the gelatin will harden into a stiff layer which holds the individual bacteria in a spot separate from his fellows. As the beef-juice and peptone are materials upon which the bacteria can feed and grow, the little organisms begin at once to multiply. After a day or two the process of increasing will have developed to such a degree that a colony composed of thousands of individuals appears where originally only a single cell existed These colonies can be seen readily by the naked eye and can be counted. By counting the number of colonies, then, we can estimate how many single bacterial cells existed in the original cubic centimeter of water.

Dr. Leffmann has said that it is a matter of considerable difficulty to make the gelatin culture-medium, and that different batches of the medium may vary so much from one another in their composition that the numbers of bacteria found in two separate tests will not always be the same. The amount of acid which the gelatin contains is an important factor. For instance, if I make use of a gelatin which contains 1 per cent. of acid and Dr. Robbins uses a gelatin which contains 2 per cent., the bacteria which find 2 per cent. favorable for growth will develop in greater numbers upon his gelatin than they will upon mine. If we make tests upon the same sample of water, and if the bacteria present belong to species which grow better in 2 per cent. than in 1 per cent. of acid, he will report that the water contains more bacteria per cubic centimeter than I shall find. As a result of long and careful study, however, bacteriologists have come to the point at last of using a nutrient medium made under standard conditions. As a result of this it is possible nowadays to make samples of culture-media which are so much alike in composition that about the same numbers and kinds of bacteria will develop one year that grew the last.

If, then, we collect one sample of water from the river, another from the reservoir, and a third from the effluent of the filters, mix them with portions of our standard nutrient gelatin, grow them under the same conditions of temperature, period of cultivation, and general laboratory manipulation, the numbers of bacterial colonies which develop can be compared; that is to say, if 100 colonies develop in the gelatin seeded with river-water and only one colony develops in the gelatin seeded with filtered water, it proves that the filters removed the other 99 bacteria present in the unfiltered water; showing that 99 out of 100, or 99

per cent. of the bacteria in the river-water were filtered out. This is what we mean when we say that the filters remove 99 per cent. of the bacteria.

It is important, however, to determine not only how many bacteria of all kinds are present in water, but also whether the water contains bacteria that are characteristic of sewage. Sewage contains, among other things, the fecal matter discharged from the intestines of human beings into water-closets. As this fecal matter contains thousands of the bacteria which live in the intestine, these organisms pass into the sewage with the fecal matter. As typhoid germs live in the intestines of persons suffering with this disease, they pass into the sewage, as well as other kinds of bacteria in the evacuations from typhoid patients. The typhoid bacillus is difficult to identify in water because we cannot subject the organism (after it has been isolated) to the crucial test of introducing it into the body of a human being and noting that it produces the disease. For that reason we do not undertake to find typhoid bacilli in water, but rest content with hunting for other organisms which are found in fecal matter. The species of bacterium referred to is called the Bacillus coli communis. This organism can be identified because it forms certain characteristic reactions. For instance, it will grow at the temperature of the body, which is 37 degrees Centigrade. It will produce acid in the presence of milk-sugar; this acid can be detected by the fact that it will turn litmus from blue to red; the colon bacillus will ferment a solution of sugar, forming carbonic acid gas, hydrogen, etc. The bacillus will turn milk sour, making it curdle, etc., etc.

The majority of bacteria found in a river-water came from the fields and woods. These organisms will not grow at the temperature of the body. If, then, we make a mixture of the water to be tested with a mixture of agar, beef-juice, litmus, etc., and place them at the temperature of the body in an incubator, the soil forms will not grow but the fecal bacteria will. In that way we eliminate the great numbers of bacteria contained in river-waters, such numbers as you have seen thrown on the screen to-night. For instance, I saw one number there of 160,000 per cubic centimeter. It is not unusual to find as many as that when the river is muddy. When, however, we put such a water as that at 37 degrees Centigrade, the number of bacteria which develop will be reduced to 200 or perhaps 300 per cubic centimeter; moreover, as the fecal bacteria, for which we make tests, form acid in the culture-medium, the colonies of the Bacillus coli communis will be red, because they produce an acid which turns the litmus agar from blue to red. In view of the fact that the Bacillus coli communis is not the only intestinal organism which will turn the litmus red, it is necessary to subject the bacteria which form red colonies to the series of tests noted above—that is, to sugar solutions, milk, etc. If the bacteria which turned the litmus red give the proper reactions in the control tests, it is evident that the Bacillus coli communis was present in the water. As the typhoid bacillus comes from the same locality as the colon bacilli, if we find the latter in the water the typhoid may be there also. We make tests upon the filtered water at frequent intervals, and the typhoid statistics of the Third Ward bear out the findings of our laboratory tests, for the cases of typhoid fever have been reduced by about 75 per cent. in the portion of the Germantown district which has received filtered water continuously for the past year.

With regard to the numbers of bacteria in the reservoir water, I must take

exception to Dr. Leffmann's suggestion that they are higher in the reservoir than in the river, because the water is warmer in the reservoir than in the river; and that the bacteria grow in the warmer water. Mr. Maignen has pointed out that these high numbers were found during the cold weather in the winter. During the winter months the reservoir was covered with ice and the temperature of the water in the reservoir was the same as that in the rivers. For that reason we must find some other explanation for the differences in the numbers. The probable explanation is that the samples do not represent the same water. The reservoir has considerable storage capacity—perhaps two or three days. The floods come so suddenly in the river and are of such short duration that, while to-day there may be only 5000 bacteria in a cubic centimeter, to-morrow there may be 50,000, and the next day only 15,000. When this water is pumped into the reservoir it will affect the water stored there to such a degree that the numbers of bacteria will be higher in the reservoir on the day after a flood has passed down the river than they are in the river at the same time. For that reason, as Dr. Leffmann said, it is not safe to depend upon a single test, but the tests should be continued over a series of days. We get the greatest value from our tests by comparing the results of to-day with those of yesterday, or of the winter with those of the summer, rather than by comparing two tests made on the same day.

George R. Henderson.—I have heard remarks about the cost of filtration plants, reservoirs, and bacteria, and it has occurred to me that perhaps it would be an advantage to consider the thing in a little different light. What is the object in removing bacteria from water that is to be used for washing buggies, putting out fires, sprinkling streets, etc.? Why should we have *any* bacteria in the water that we wish to drink or cook with? From the figures which Mr. Maignen furnished us it is apparent that something over two hundred gallons of water per day per capita are used in this city. It is probably a conservative statement that not over two gallons a day are used for drinking or cooking; which would be 1 per cent. Why would it not be good policy, in planning new waterworks, to give large quantities of unfiltered water that could be used for sprinkling streets, putting out fires, cleaning closets, etc., and then to furnish a small supply of sterilized water, which could be boiled, or, if that is not sufficient, distilled water? This might be furnished in a small system of pipes and mains which could be put in the same trench with the large pipes and introduced at the same time. While I have not made any figures, it seems to me the cost of this extra small piping and the very small installation needed for purification would certainly be less than the enormous expense of filter beds and reservoirs; we could then do away with reservoirs altogether, which are considered to be breeders of bacteria, and by using what has been generally termed the Holley system, we could pump direct into the mains and deliver every day as needed. I would be glad to have any criticisms on this suggestion.

Mr. Copeland.—I would like to say, with regard to the remarks of the gentleman who has just been speaking, that the duty of the community is to protect the lives of its citizens. The duty of the manufacturer should be to protect the lives of his employees. It is not always possible, however, for the manufacturer to meet that requirement. For instance, if we have two supplies of water in a town, one of them being purified for drinking-water and the other left unpurified, it is unfortunately true that many of the people in the community will drink

from that unpurified supply, in spite of all precautions, signs, warnings, or anything that the Board of Health or that the manufacturer or that a man's best friend can do to prevent it.

Mr. Maignen.—It does seem a very strange thing to use sterile water for sprinkling purposes. There are in Paris two sets of water-pipes, one for the raw river-water, the other for spring-water, which, by the way, is not altogether satisfactory. Most of the springs are shallow and they become easily polluted in times of rain, and every now and then typhoid fever appears among the population in Paris who drink this so-called spring-water. The typhoid fever will not be stopped in Paris any more than anywhere else until all the water intended for drinking, whatever may be its origin, is filtered with great care.

# ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, April 2, 1904.—President Carl Hering in the chair. Seventy-six members and visitors present.

Dr. Henry Leffmann gave a short account of "The New Geometry." Mr. Harrison Souder presented a paper on "The Failure of the Oakford Park Dam at Jeannette, Pa."

Regular Meeting, April 16, 1904.—President Carl Hering in the chair. Ninety members and visitors present.

The death of E. Percy Teal was announced.

Mr. P. J. A. Maignen presented a paper on "The Lower Roxborough Preliminary Filters."

Business Meeting, May 7, 1904.—President Carl Hering in the chair. Seventy-eight members and visitors present.

The death of C. P. Weaver was announced.

Professor A. Vosmaer, visitor, presented the subject of "The Sterilization of Water by Ozone."

The Tellers reported the election of Messrs. Francis H. Albright, J. A. P. Crisfield, Ad. Fischer, and George L. Miller to active membership.

Regular Meeting, May 21, 1904.—President Carl Hering in the chair. Eighty members and visitors present.

Mr. C. H. Ott gave "Some Examples of Recent Sewer Construction by the City of Philadelphia," and Mr. Charles Day's paper on "The Individual Operation of Machine Tools by Electric Motors" was read by Mr. Harold T. Moore.

Regular Meeting, June 4, 1904.—President Carl Hering in the chair. Seventy-two members and visitors present.

The Nominating Committee selected by the Board of Directors was announced as follows: Edwin F. Smith, Chairman; L. Y. Schermerhorn, Wm. H. Robinson, E. M. Nichols, and F. E. Dodge.

Mr. S. S. Sadtler presented some "Notes on the Use of Lutes," and Colonel E. D. Meier explained the "Recent Developments in the Diesel Engine," Mr John D. MacPherson participating in the discussion which followed.

# ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, April 16, 1904.—Present: The President, Vice-Presidents Foster and McBride, Directors Bonner, Leiper, Loomis, Davis, and Easby, and the Treasurer and Secretary.

The Treasurer's report showed:

| | |
|---|---|
| Balance, February 28, | $2785.38 |
| March receipts, | 561.25 |
| | $3346.63 |
| March disbursements, | 331.83 |
| Balance, March 31, | $3014.80 |

The President announced the appointment of the following committees: *Park System:* George S. Webster, Chairman; L. Y. Schermerhorn, H. G. Morris, Wm. Easby, Jr., Thos. C. McBride, and Harrison Souder. *Extension of Courtesies to Foreign Engineers:* James Christie, Chairman; John Birkinbine, John C. Trautwine, Jr., L. Y. Schermerhorn, J. M. Dodge, John H. Converse, and Charles H. Cramp.

The question of reinstating resigned members having been brought up, it was resolved that the sense of the Board is that resigned members must be re-elected.

Regular Meeting, May 21, 1904.—Present: The President, Vice-President Foster, Directors Leiper, Loomis, Davis, Devereux, Easby, and the Treasurer and Secretary.

The President announced the appointment of the following committees: *Committee to Urge Local Members of the A. I. E. E. to Become Members of the Club:* Horatio A. Foster, Chairman; Wm. C. L. Eglin, and Charles Hewitt. *Committee to Urge Local Members of the A. S. C. E. to Become Members of the Club:* L. Y. Schermerhorn, Chairman; James Christie, and George S. Webster. *Committee to Urge Local Members of the A. S. M. E. to Become Members of the Club:* H. W. Spangler, Chairman; W. P. Dallett, T. Carpenter Smith, S. Kneass, C. Day, W. Lewis, and G. T. Gwilliam.

The Treasurer's report showed:

| | |
|---|---|
| Balance, March 31, | $3014.80 |
| April receipts, | 297.96 |
| | $3312.76 |
| April disbursements, | 657.36 |
| Balance, April 30, | $2655.40 |

Subscription to the International Engineering Congress was authorized, so that the Proceedings of the Congress would be received for the Library.

A letter was read from the Girard Estate for a renewal of the lease for the

Club House for three months only, and the President and Treasurer were directed to sign a lease for that term.

Special Meeting, June 3, 1904.—Present: The President, Vice-President McBride, Directors Bonner, Loomis, Davis, and the Treasurer and Secretary.

The President announced the appointment of a *Committee to Urge Local Members of the A. I. M. E. to Become Members of the Club,* as follows: Benj. Smith Lyman, Chairman; George C. Davis, and S. E. Fairchild, Jr.

The Treasurer's report showed:

| | |
|---|---|
| Balance, April 30, | $2655.40 |
| May receipts, | 331.00 |
| | $2986.40 |
| May disbursements, | 875.06 |
| Balance, May 31, | $2011.34 |

The President and Treasurer were authorized to sign a lease for the Club House for one year from October 1, 1904.

The personnel of the Nominating Committee was selected as follows: Edwin F. Smith, Chairman; L. Y. Schermerhorn, Wm. H. Robinson, E. M. Nichols, and F. E. Dodge.

# ADDITIONS TO THE GENERAL LIBRARY.

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From Metropolitan Water and Sewerage Board, Boston.

Third Annual Report, 1904.

From Carl Hering, Philadelphia.

Conversion Tables, Hering.

From Henry L. Doherty, Denver, Colo.

Question Box of the Ohio Gas Light Association, 1904.

From the City Parks Association of Philadelphia.

Sixteenth Annual Report, 1904.

From J. H. Bridge, New York.

The History of the Carnegie Steel Company, 1903.

From A. J. Cassatt, President Pennsylvania Railroad.

Contract Drawings, Specifications, etc., for the work in Connection with the New York Terminal of Pennsylvania Railroad.

From Peabody Coal Company, Chicago.

The Economical Burning of Coal without Smoke, A. Bement, 1904.

From Continuous Rail Joint Company of America, Newark.

Russo-Japanese War Atlas, 1904.

From Geological Survey of Ohio, Columbus, Ohio.

Bulletin No. 1, Fourth Series, 1903.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS

OF

# THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXI. OCTOBER, 1904. No. 4

## ERRATA, Vol. XXI, No. 3.

Page 220, line 14 from bottom, read 1653 instead of 182.
Page 220, line 15 from bottom, read 71,424,000 instead of 7,866,936, and 9920 instead of 1092.

fifty years after his death, and, when the resentments of two wars and international antagonism might be expected to be active, the great historian, Macaulay (who cannot be suspected of any undue admiration for America or Americans) named George Washington as a type of the stainless politician. Even the great abuser of colonial statesmen, who calls Jefferson "timid and vacillating," Madison "helpless," and Monroe "foolish," and who, in disregard of both the facts of history and decencies of historical discussion, has called one of the most active of revolutionary patriots "a filthy little atheist," has words of approval for Washington.

The military and political incidents in Washington's life have been

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# GEORGE WASHINGTON AS AN ENGINEER.

HENRY LEFFMANN.

*Read September 17, 1904.*

GEORGE WASHINGTON, General of the armies of the Continental Congress, President of the Constitutional Convention, and first President of the United States, is conspicuous among the heroes of all times and places. Few men have exhibited such strength of character united with sincerity and simplicity of method; few men have deserved and received such great respect and admiration for their qualities. Even some of those who, by descent, might be expected to feel enmity toward him have been prominent in declaring his virtues. Less than fifty years after his death, and, when the resentments of two wars and international antagonism might be expected to be active, the great historian, Macaulay (who cannot be suspected of any undue admiration for America or Americans) named George Washington as a type of the stainless politician. Even the great abuser of colonial statesmen, who calls Jefferson "timid and vacillating," Madison "helpless," and Monroe "foolish," and who, in disregard of both the facts of history and decencies of historical discussion, has called one of the most active of revolutionary patriots "a filthy little atheist," has words of approval for Washington.

The military and political incidents in Washington's life have been

treated at such length that there is scarcely further need for work along this line, but it is, nevertheless, true that a sufficient biography of the man has not yet been written. Phases of his character that are deserving of much admiration are overlooked in the brilliancy of his later life. The prominence of Washington the Commander and President hides the merit of Washington the citizen and subaltern.

It has been for some years my wish to bring before the Club an account of Washington's work as an engineer, about which comparatively little is said. It is, of course, known to all who have more than the school-book knowledge of the man, that he was, in early life, a land surveyor, but the extent and character of his work in this direction, and the early views he entertained and advocated concerning great engineering operations, are not widely appreciated. Most of his biographers pass rather rapidly over those phases of his career in which he was connected with arts of peace, finding more attractive materials in his campaigns, beginning with those under the flag of England and ending with those under the Stars and Stripes.

The material for the biography of Washington is fortunately unusually abundant and authentic. It consists largely of his own writings. These begin at a very early age. He was minute and painstaking in the records of all his doings. His diaries are not filled with the gossip of courts or camps, but with accurate and comprehensive notes of actual work. If genius is correctly defined as "an infinite capacity for taking trouble," Washington stands as one of the greatest of geniuses, for the habit of carefully recording his work began in childhood and continued throughout his very active life. These records are mostly preserved, the bulk of them now resting securely in the Library of Congress.

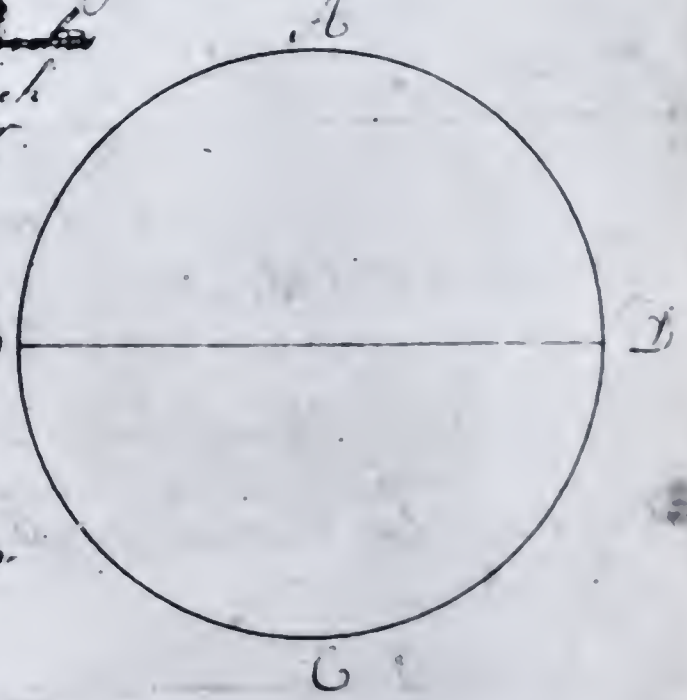
It is to be regretted that the United States authorities have not yet seen fit to reproduce all this material by the excellent photographic methods now available, and thus place the records at the disposal of all who are interested in the subject. Some enterprising citizens have attempted to remedy this defect, and have accomplished considerable, but their transcripts, however carefully made, cannot take the place of photographic reproductions. Among the most serviceable transcripts of the Washington records are those made by the late Dr. J. M. Toner. I am much indebted to his work for the material I use in this essay. Dr. Toner intended to reprint all the Washington material to which he could secure access, but did not accomplish the entire task.

# Geometrical Problems

## Problem 29th

How to Measure a Piece of Land in the form of a Circle
Multiply the Diameter into it self, and Multiply that Product by 11 and divide by 14 the Quotient is the Area of the Circle

In this Circle A.B.C.D. let the Diameter thereof be 50 Perches which Multiplyed in it Self gives 2464 this Number Multiplyed by 11 gives 27104 which being divided by 14 the Quotient will be 2721 that is the Area of the Circle




The Diameter and Circumference being thus known the half of each of these Multiplyed together gives the Content in Perches which Divided by 160 the Quotient gives the Content in Acres

```
   50
   50
  ---
  464
 800
 ----
 2464
   11
 ----
14)27104(2721
   28
   ---
   101
   ---
    98
    ---
     30
     28
     ---
      24
      14
      ---
      10
```

```
  2721     50
  ----     --
  1360     29
    29
  -----
  12246
  2720
160)39410(246
    32
    --
     74
     64
     ---
     104
      96
      --
       80
```

Ans. 246 Acres the Content

FACSIMILE OF A PAGE OF WASHINGTON'S SCHOOL COPYBOOK.

Photographed from the original in Library of Congress. There is a mistake in multiplication, and in the application of a rule.

Washington was not a college man. He had no training in the classics, hence we miss in his writings those scraps of Horace, Homer, and Cicero that are so common in the writings of his period and are still often observed in this less classical age. This is no loss, for we have in place of such allusions, unaffected expressions of sentiments and simple recital of facts.

Even as to the French language, which in his day was the language of the cultured classes of all Europe, and which he must have heard more or less in his home, he was so deficient that he was unable to understand the articles of capitulation of Fort Necessity. He signed these, after verbal translations of them by one of his staff, and, as appeared later, was deceived on some points.

Washington had some sense of humor, but not nearly so much as some of those who labored with him in his great works. He was entirely different from Thomas Paine and Benjamin Franklin. He could not have written "Common Sense" or edited "Poor Richard's Almanac." Indeed, he took himself rather seriously, and his early training in aristocratic surroundings, while it did not corrupt his sense of justice or render him indifferent to rights of mankind at large, naturally developed a conservatism in politics and religion and a reserve in manners which would today probably seriously restrict his popularity. He was entirely satisfied during a large part of his life to owe an allegiance to a hereditary monarch, and he gave his best efforts in obedience to that allegiance. He was opposed to the movement for independence of the colonies in the initiative disputes with the mother country, as indeed were many colonial statesmen, but he bowed to the logic of events and was second to none in his readiness to make sacrifices for the cause of independence. Looking at the question without the knowledge of events, as he was obliged to do, it seems, indeed, that Washington and his immediate associates had more to lose than gain by independence. As landed gentry, holding large tracts of territory by patents from the Crown, they might consider themselves more secure than in a republic, in which socialistic and communistic notions may arise and spread with great rapidity. We must give great credit to the men who risked their lives and fortunes in the revolutionary cause. Many of the well-to-do were not so self-sacrificing.

Notwithstanding the conspicuous life of Washington and the large amount of autograph material that has been available to historians for over a century, the real Washington is not yet known. The myth-making tendencies of mankind have been exercised upon his personality

and he has been enveloped in a haze of legend and misrepresentation that partially hides his merits from us. I do not now refer to the cherry-tree story, which has been relegated by sensible persons to the limbo of amusing inventions, but to the more serious works of his biographers. Some of these, in an excess of zeal, have deemed it necessary to suppress the evidence of his human temperament, to pass unnoticed his occasional bursts of passion and the strong language that expressed his feelings at those times, to correct the slips in grammar and spelling that are by no means infrequent in his letters and memoranda. Concerning this latter point, it is but fair to note that in Washington's earlier days less care than now was exercised in literary composition by many persons, especially those outside of strictly literary circles. If we may trust the official reprint of the Pennsylvania Colonial Records, Patrick Gordon, Governor of the colony, in a proclamation issued a few years before Washington was born, spells the pronoun "their" two different ways in the same paragraph.

Dr. Toner, to whom I have just referred, regards this question in a scientific spirit, and in his transcripts of the Washington memoranda has retained the forms exactly as he finds them.

Washington was a great engineer. His claim to rank in this honorable station rests not upon great constructions, but upon the forethought that he exhibited in regard to the necessity of certain engineering operations and the energy, ability, and disinterestedness with which he advocated his views. These suggestions were not based on theoretical speculation, the studying of maps, or listening to the relations of travellers. While yet a lad, he left a comfortable home to spend a long period in the wild regions of the head-waters of the Potomac, Youghiogheny, and Monongehela. When, in the early part of 1748, just after he passed into his sixteenth year, he made the expedition into the interior of northern Virginia, to survey the lands of Lord Fairfax, he ventured upon as great a task as would now characterize a journey to the poles or to the interior of Alaska or Africa. For it must be remembered that the means of dealing with natural difficulties were far cruder than at present, and that while the weapons of offense and defense available to civilized men were superior to those of savages, yet they were far inferior to those now in use. The old flint-lock musket did not excel the bow and arrow in skilful hands as much as we might now suppose. Indeed, at the opening of the Revolution, Benjamin Franklin (who was certainly not a visionary or a crank) suggested arming the colonial troops with bows and arrows in prefer-

ence to muskets, and adduced several reasons in favor of the older weapons. Accurate, rapid-firing, breech-loading rifles, of light weight and long range, with compact, waterproof, self-primed cartridges, make modern operations against hostile savages much safer than in Washington's day.

At the time these journeys were made no swifter methods of forwarding men, material, and news were available than by use of the horse. The roads were mostly rude openings through the forest, maps were imperfect, derived partly from the statements of venturesome Indian traders, trappers, or fortune-hunters, not always sure to relate correctly what they knew, liable even to give false information or to exaggerate dangers, with a view of deterring competition. The common people, from whom the bulk of the expedition was recruited, were more or less superstitious and liable to be discouraged by signs and omens interpreted according to their folk-lore.

Washington's proficiency in the procedures involved in engineering enterprises was manifested in very early life. His school copybooks, which are still in existence, show neatness and skill in mathematical work and in geometric drawing. His first remunerative labor of which we have definite record was in surveying portions of the lands of Lord Fairfax, located in what was then known as the "Northern Neck" of Virginia, now included, in part, in West Virginia. During the spring of 1748, when Washington had just turned sixteen years of age, a considerable emigration of settlers was taking place into the region of the Shenandoah, and a need for land-surveying arose. The great grants of land by European monarchs to favorites or adventurers (the latter term not then being a derogatory one) were often made vaguely, by assigning some line of longitude or latitude, or based on incomplete and erroneous maps. The office of surveyor was in good repute; persons of good social position could undertake it without derogation. That Lord Fairfax should have chosen for the important task of such surveys a youth not yet seventeen, speaks for the ability and trustworthiness that must have been recognized in young George, and the sequel amply demonstrated that Lord Fairfax made no mistake.

Washington's pen was active in early childhood. He was not, however, a literary genius. He was strictly practical. It is true a few lines of rhyming dissertation on love are found scribbled upon the spare pages of a memorandum book, but these cannot add to his fame. The following are selections from these:

'Twas Perfect Love before }
But Now I do adore } s: Young M; A: his W

Oh Ye Gods why should my Poor Resistless Heart
Stand to oppose thy might and Power
At Last surrender to cupids feather'd Dart
And now lays Bleeding every Hour.

His earliest connected writing is a version of a series of rules for behavior, entitled "Rules for Civility and decent Behavior in Company and Conversation." It was formerly supposed that it was original, but it is now known that in the main it is from the French; but, as he did not understand that language, the translation was not by him.

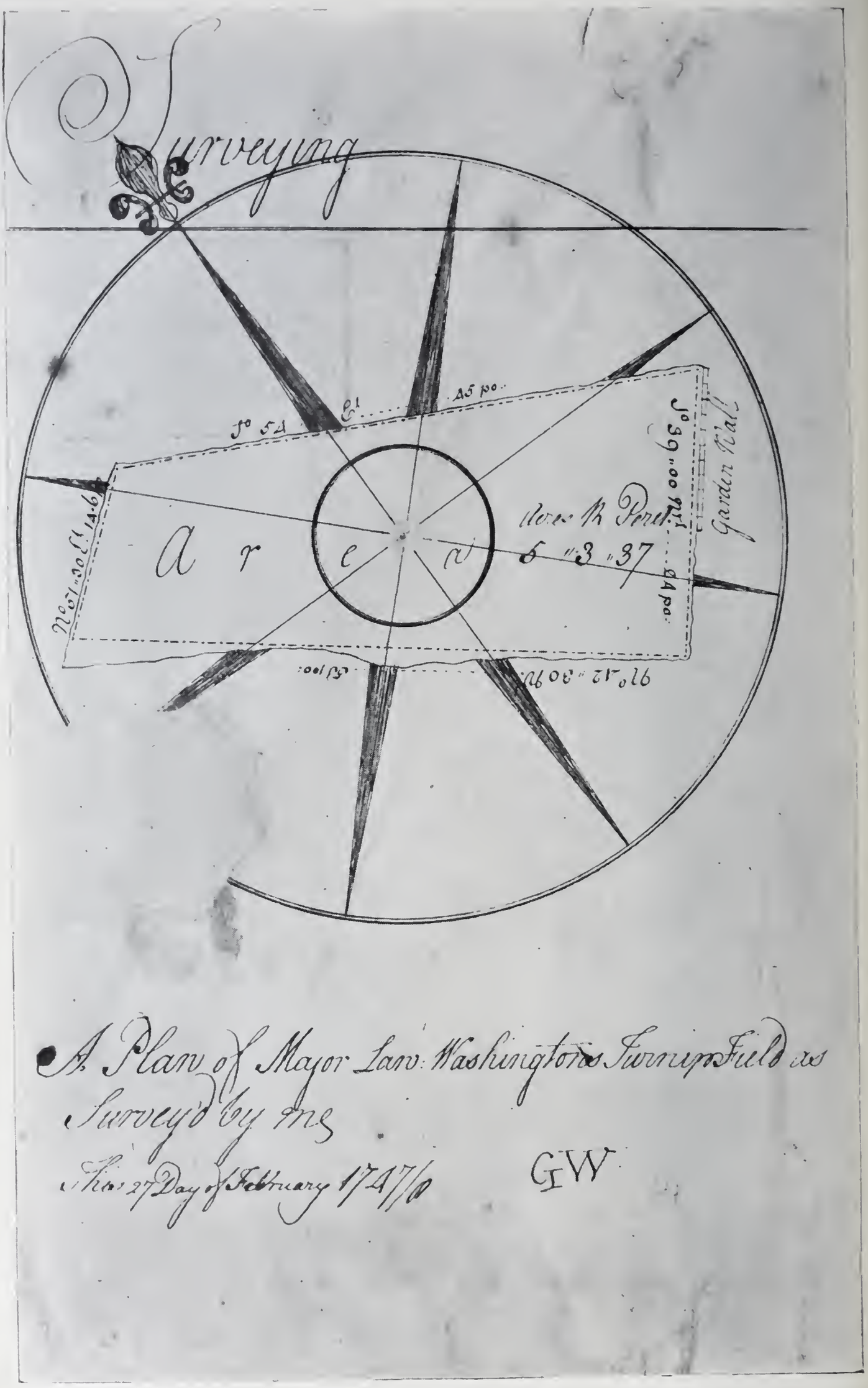
While visiting at the house of his brother, Lawrence Washington, at Mount Vernon, he amused himself and entertained others by surveying plots of ground and making maps. One of these, a map of Lawrence's turnip field, is still in existence, and a facsimile is annexed. The date is sixteen days after the sixteenth anniversary of his birth, as the chronology is "old style," a fact that is further indicated in the year-mark. The year 1748, according to one system, began on January 1st; according to another, on March 25th. To avoid ambiguity in dates during the intervening period, both year-numbers were written.

Much attention is being given at the present day to the determination of character from handwriting. I think there is considerable basis for the theory that principal traits may be determined by a such a study. I see in the handwriting of this map, especially the legend "surveying," evidence of Washington's traits. Deliberation, thoroughness, attention to detail, practical rather than sentimental tendencies, are exemplified.

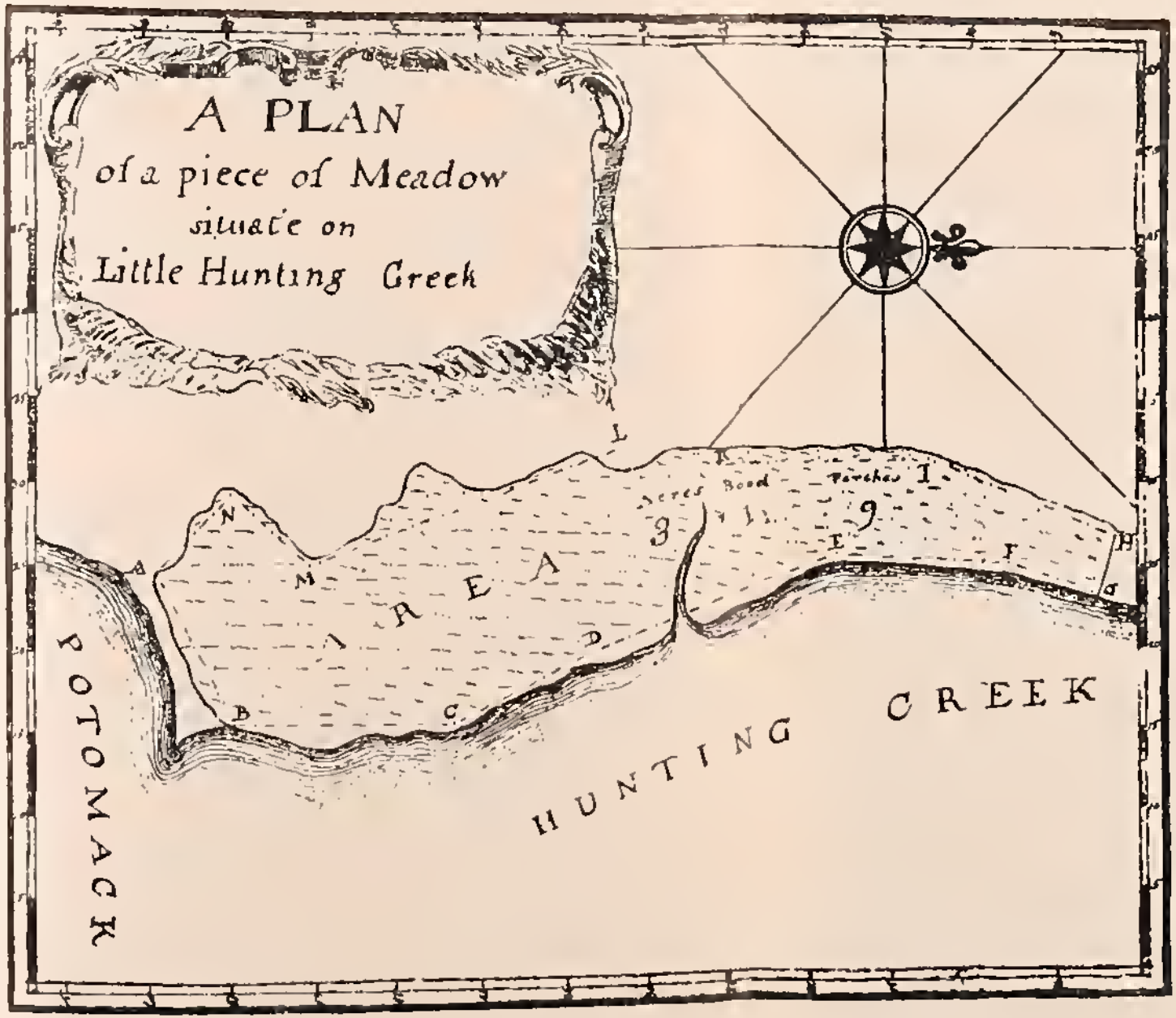
The notes of the surveys made for Lord Fairfax are in considerable part extant, and have been reprinted with great care by Dr. Toner. They begin with an entry "A Journal of my Journey over the Mountains began Fryday, the 11 of March 174–78.

"Fryday, March 11th 1747–8. Began my Journey in Company with George Fairfax, Esq., we travell'd this day 40 miles to Mr. George Neavels in Prince William County."

This start was made from the estate of Hon. William Fairfax, which, in a letter written many years later, Washington described as "within full view of Mount Vernon" and separated therefrom only by water. A few lines of the diary may be quoted exactly as written:




MAP MADE BY WASHINGTON WHEN JUST PAST SIXTEEN.
Photographed from the original in Library of Congress.




Facsimile of a Map from the collection of the late Moses Polock, now in possession of The Rosenbach Company of Philadelphia. Upon the back of the Map is a brief note in Washington's handwriting. The map was probably made at an early date.

*Tuesday 15th We set out early with Intent to Run round ye sd Land but being taken in a Rain & it Increasing very fast obliged us to return, it clearing about one oClock & our time being too Precious to Loose we a second time ventured out & Worked hard till Night & then return'd to Penningtons we got our Suppers & was Lighted into a Room & I not being so good a Woodsman as ye rest of my Company striped myself very orderly & went in to ye Bed as they called it when to my Surprize I found it to be nothing but a Little Straw—Matted together without Sheets or anything else but only one thread Bear blanket with double its Weight of Vermin such as Lice Fleas &c I was glad to get up (as soon as ye Light was carried from us) I put on my Cloths & Lays as my Companions. Had we not have been very tired I am sure we should not have slep'd much that night I made a promise not to Sleep so from that time forward chusing rather to sleep in ye open Air before a fire as will appear hereafter*

The journal gives many notes of surveys, written in the same manner as to spelling, use of capitals, and absence of punctuation as exemplified in the extract given. In addition to the fact already mentioned, that in Washington's time somewhat more laxity existed in these matters, it must be borne in mind that these are merely rough notes intended for his own guidance. He had no thought that they would ever be of interest to any one; much less that they would be treasured and published. As a matter of fact, he was much more careful in writings intended for transmission to others or for publication, making rough drafts first and then recopying these after correcting.

This journal ends, as far as regards memoranda of the journey, on Wednesday, April 13, 1748 (O. S.), the entry being:

*Mr Fairfax got safe home and I myself safe to my Brothers which concludes my Journal*

Many notes of surveys are entered, however, of later date up to November 3, 1750 (O. S.). I transcribe one of these as an illustration of the style:

*April 2d* 1750

*Then Survey'd for Even Pugh a certain Tract of Waste and ungranted Land Situate in Frederick County on the Trout Run a branch of Cacapehon & bounded as followeth beg^g at a white Oak & two Poplars stand^g on the Run & Run thence S 85 E^t Three hun^d and twenty Poles to two red Oaks two Gums & a Maple thence*

*N° 40° W Three hund^d & twenty poles to a white Oak from thence to the Beg^g S 27 W^t 244 Po Con^g 226*

*Plat drawn*

DAVID EDWARDS } *C : M*
JOSEPH POWELL }
EVAN PUGH JUN^R *Mark*

C: M stands for chainmen; Mark, for marker.

By the death of his brother, in 1752, Washington became the owner of Mount Vernon. While he did not do much detail survey work after this, yet he was very active in exploration, and in all his journeys he kept records, and observed facts that were to be applied by him in the furthering of great engineering enterprises.

In 1754 he went on a mission to the French, then actively operating in the region around Pittsburg. The journal of this march fell into the hands of the enemy. Considerable portions of it were subsequently printed in French, with annotations, largely directed to showing the unjust character of the British movements.

It was on this march that, at Fort Necessity, on July 3, 1754, he had the first encounter with the armies of the French king, and after a gallant struggle surrendered.

In the years immediately preceding the Revolution, Washington made several journeys to the territory of the Ohio and its head-waters. He had already perceived the great problems involved in the settlement of this region, especially in relation to the colonies. At that time he was, of course, a loyal subject of George III, and nothing was further from his thoughts than that he should break that allegiance. He recognized the two dangers with which the English dominion was threatened, the encroachments of Spain and France. The latter were settling and fortifying the regions immediately to the west of the colonial line, and the government established there was in two aspects objectionable to Washington and all who were closely associated with him. The French were the long-standing enemies of the English and their monarch was the champion of that phase of Christianity against which the English had fought so bitterly and which was held in such detestation and fear that its adherents had for many years been debarred from some civil rights in England.

Washington saw that the ranges of mountains lying to the immediate westward of the well-settled portions of the colonies were barriers, geographically, socially, and politically, and that, unless early efforts

Facsimile of a Map published in connection with a collection of "Letters from His Excellency General Washington to Arthur Young, Esq., F. R. S." London, 1801.

The following Map of the Cayuga, or Tioga Branch of the Susquehanah, is called down by guess from an acc.t in B.r Sec.y Hand's letter of the 31st March 1779 — as given to him by an old Sen.r of Northampton County in Penn.a who formerly lived at Chemung — but had not been in that Country for 23 years.

From Tioga ... Miles
to Chemung ..... 15.
Tough peehan . 15
Sipsing ..... 25
Little Possica ... 8
Great Possica . 27
Small to g.a Possica 90
Seneca Fort. Lake 30
120

From g.r Possica to a hunting Cabin on Allegany ... 3 days
thence to Tillaseing . 3 D.o

From g.a Possica to the Water of Allegany ..... 12 Miles
thence along d.o to French Creek + ..... 30

The Country from Tioga is in gen.l level up to g.a Possica — also across to Allegany

+ This must be a mistake — the distance to F.C. must be greater

FACSIMILE OF MAP MADE BY WASHINGTON IN 1779, FROM DATA OBTAINED BY HIM FROM SEVERAL SOURCES, AS A GUIDE FOR AN EXPEDITION AGAINST INDIAN ALLIES OF THE BRITISH.

Photographed from the original in Library of Congress.

were made to establish some means of convenient transportation, alien influences would arise, and hostile nations be created on the colonial borders.

At that time no plans could suggest themselves but the construction of roads and water-ways. The railroad was unthought of. Roads over mountains would be expensive to construct and operate. The far-seeing men of that day (for Washington was not alone in these matters, but he was foremost and among the best equipped for proper judgment) turned to the question of water-transportation, and, by the improvement of the rivers and the construction of canals, hoped to accomplish their purpose. Difficulties of several types were encountered. The colonies were poor. The enterprises did not possess that excitable quality that leads to widespread speculation, nor were the promoters of the plans men who would have cared to take advantage of this weakness of human nature. The colonies were not nearly so friendly as could be desired. It is a common opinion that the thirteen colonies that afterward united in prosecution of the war were always living in affectionate relations, but this is not true. Political and social enmity was rife. Disputes about boundaries were active. Connecticut, for instance, claimed the territory directly westward, which if conceded would have taken off nearly one-half of Pennsylvania.

All plans for these internal improvements were interrupted by the events that took place in the early seventies. The dramatic incident at Concord bridge was followed by the battle of Bunker Hill, and the Continental Congress recognized that it must begin at once to organize an army. On June 15, 1775, the Congress unanimously chose George Washington, Esq., General of all forces raised or to be raised in defence of American liberty. From that time until the 23d day of December, 1783, he was entirely occupied with war. The transportation problems which he had so carefully studied were set aside. Yet we may be sure that his training in this field of work stood him in good stead in all his military operations, and that the success of the colonies was due not a little to the fact that the general of their armies united to the qualities of integrity, bravery, and attention to detail, the attainments of a practical engineer.

On the 23d of December, 1783, Washington resigned unconditionally his military authority. Of the momentous nature of this step and of its influence on the future history of the nation it is not necessary here to speak. He had earned fully the right to retire to private life and

to leave to others the civil duties that had arisen. The condition of the colonies at the close of the Revolution was in some respects worse than before it. They had gained independence, they had maintained successfully the principle that taxation without representation is tyranny, but, on the other hand, they had lost the protecting arm of what was probably the strongest nation in the world. They had, it is true, the support, in some way, of the French, but, as events soon proved, this was of no value, for within a few years came the fall of the Bastille, the overthrow of the monarchy, and the Terror. Indeed, before the century expired, a war between the friends had actually broken out.

The thirteen colonies were bound by a loose federation; there was no strong central authority. Local conditions, territorial and other disputes were beginning to work disintegration. Washington saw clearly that there were few influences better adapted to cementing these inter-colonial bonds than a community of business interests.

Though he had relinquished his official positions, he had not relinquished his interest in his country, nor did he contemplate a life of ease and idleness. He began at once to make explorations and investigations into the question of internal improvements. In the autumn of 1784 he made a tour to the region included between the head-waters of the Potomac and Ohio, to renew his knowledge, to observe the progress of settlements, and to be enabled to formulate more precisely plans for the construction of a public highway across the mountains. Shortly after his return from this expedition, October 10, 1784, he wrote a long letter to Benjamin Harrison, Governor of Virginia, in which he set forth in much detail the views he held and the difficulties to be overcome.

Letters were written by him to several other persons calling attention to the plans he had formulated. One to Marquis Chastelleux, which is printed in Hon. Andrew Stewart's report (1st Sess., 19th Cong., No. 228, H. R.), will show his views vividly:

> "I have lately made a tour through lakes George and Champlain, as far as Crown point, then returning to Fort Schuyler, crossed over to Wood creek which empties into Onieda lake and affords water communication with Ontario. I then traversed the country to the head of the eastern branch of the Susquehannah, and viewed lake Otswego and the portage between that lake and the Mohawk River at Conajoharie. Prompted by these actual observations, I could not help taking a more contemplated and

extensive view of the vast inland navigation of these United States * * * * * * I shall not rest contented until I have explored the western country, and traversed those lines (or a great part of them) which have given bounds to a new empire."

Among his manuscripts are some calculations as to the comparative distance by water routes and roads, as follows:

Distance from Detroit to the several Atlantic seaports.

From Detroit by the route through Fort Pitt and Fort Cumberland

| | | |
|---|---|---|
| To Alexandria | 607 | miles |
| " Richmond | 840 | " |
| " Philadelphia | 745 | " |
| " Albany | 943 | " |
| " New York | 1103 | " |

About this time Washington made a map showing the water-courses of the Potomac and Ohio and the relation of them to the main divide between these river-systems. A facsimile of this has been obtained from Stewart's report. The plan, it will be seen, was to establish a portage across the divide. This is indicated by the dotted line A B. More than a quarter of a century afterwards the United States engineers, after their surveys, laid down a portage line only about a mile below that suggested by Washington. Another and longer line of portage is indicated from Cumberland into a region which is now part of Fayette County, Pennsylvania. He had studied this latter region in his campaign of 1754, that ended in the disaster at Fort Necessity.

In connection with these plans he prepared a statement as to the difficulties to be encountered, partly as follows:

"From the mouth of Patterson's creek to the beginning of Shenandoah falls, there is no other obstacles than shallow water, thence for six miles, rocky, swift and uneven water, in which distance there are four falls; the first tolerably clear of rocks, but shallow, may be much amended by a passage on the Maryland side. Two miles from this. and half a mile below the Shenandoah is the spout, a considerable rapid of swift and uneven water, which is confined to a narrow passage; a passage to avoid this by removing some rocks on the Maryland side may be had. One of the other two falls is also swift and ugly, not much unlike the spout, but a passage between. Eight miles lower down is another fall, but easy and passable. Two miles further are a cluster of small Islands with rocks and rapid waters—from hence to Seneca Falls fine smooth water; Seneca falls not very difficult."

MAP MADE IN 1784 BY WASHINGTON TO SHOW THE GENERAL PLAN FOR OPENING COMMUNICATION BETWEEN HEAD-WATERS OF POTOMAC AND OHIO RIVERS.

Photographed from facsimile in report of Hon. Andrew Stewart. (19th Cong., 1st Sess., H. R.)

In a communication to Governor Johnson (of Maryland), who favored a limited enterprise, he wrote:

"Whereas if it was recommended to the public notice upon a more enlarged plan, and as a means of becoming the channel of conveyance of an extensive and valuable trade of a rising empire," going on to say that the effort to form a company to explore the plan would be more likely to be successful if undertaken on a large scale.

The result of the active and intelligent propaganda carried on by Washington was that the citizens of Virginia took up the question of the improvement of western transportation. Local jealousies, even within the State, were such that in order to secure the interest of some sections a second scheme had to be included, namely, the improvement of the James River.

In the latter part of 1784 a bill was passed by the Legislature of Virginia providing for the incorporation of companies for these purposes. Washington at once wrote to Madison, then a prominent member of the Virginia legislature, earnestly recommending the appointment of commissioners with full powers to consult with commissioners that might be appointed by the Legislature of Maryland (the concurrent action of which was necessary to any operations on the Potomac). These joint commissioners were to prepare a bill that would be acceptable to both States. The Virginia Legislature promptly agreed to this suggestion, and the commissioners named were George Washington, Horatio Gates, and Mr. Blackburn. On December 22d the commissioners met those designated by the Legislature of Maryland, among whom was Charles Carroll of Carrollton, and organized by appointing Washington as chairman.

After much discussion a report was unanimously adopted, the features of which were that joint action should be taken by the two States to open the navigation of the Potomac to boats of light draft, and that roads be constructed at points at which navigation is not practicable, such roads being laid out so as to pass through Maryland and Virginia only and avoid Pennsylvania soil.

Bills embodying these plans and providing for incorporation of "The Potomac Company" were soon drawn and passed by the States concerned. Passing over the many formal clauses of the law, it will be sufficient to quote the following, which suggests the scope of the work:

> That the tolls hereinbefore allowed, to be demanded and received at the nearest convenient place below the mouth of the South

Branch are granted, and shall be paid on condition only, that the Potomac Company shall make the river well capable of being navigated in dry seasons by vessels drawing one foot water, from the place on the North Branch at which a road shall set off to the Cheat River, agreeably to the determination of the Assemblies of Virginia and Maryland. * * *

In testimony of the public appreciation of the value of Washington's services the Legislature of Virginia passed a bill vesting in him fifty shares of the Potomac Company and one hundred shares of the James River Company. News did not travel in those days as it does now, nor was it collected or published in modern fashion. No yellow journal existed which could announce these facts in red letters, three inches long, on the front page, together with interviews with prominent parties.

The Governor of Virginia, Benjamin Harrison, by letter advised Washington of the action of the Legislature. Washington replied in a letter that ought to be read by every citizen of the United States. In this he requested that the gift be made to him only in trust, so that he might by will devise it for public purposes.

On May 17, 1785, a public meeting of the shareholders of The Potomac Company was held at Alexandria, Va., and it was reported that 403 shares of the stock had been subscribed at £100 per share, or, as the act expressed it, $\$444\frac{4}{9}$, a total of nearly $180,000. The company was organized and Washington was elected president.

It will not be necessary to follow in detail the course of its history. The difficulties in its work were great, and it failed after a long struggle, but, like so many other enterprises and efforts, its failure showed the way to successes. The construction of the Erie Canal showed that more could be done in aid of water-transportation by such method than by slack-water systems in torrential streams.

> "'Tis not in mortals to command success,
> But we'll do more, Sempronius, we'll deserve it."

Washington did not use this motto, possibly he did not know it, but he represents its principles. He had done everything that could be done in his time to the furtherance of the plan, and if other methods of transportation had not been invented, a completion of the work, even at large outlay, would have been required.

An interesting item in the minutes of the company is the record of trouble with laborers, and a resolution to appoint agents at Baltimore

and Philadelphia to *purchase* sixty servants for the use of the company. The plan apparently failed, for later it was decided to hire laborers.

Washington continued to serve as president until 1788, when it became evident that he would be called to a presidency of greater moment.

In 1822, after thirty-six years of effort, and the expenditure of over $700,000, the Potomac Company went to pieces, and upon its ruins arose The Chesapeake and Ohio Canal. In all these years only one dividend ($5.50 per share) had been paid.

The James River Company was more fortunate. It was organized in 1784 with a stock of 500 shares at $200 per share, and by October, 1785, $98,600 of this had been taken. By 1790, a considerable part of the canal was in operation. Washington was offered the first presidency, but could not accept. After the enterprise was well established, it was taken over by a new company, the original stockholders receiving an annuity of 15 per cent. on a capital of $140,000, a total annual rental of $21,000.

By act of legislature, Washington had been presented with 100 shares of this stock, which he accepted only as a trust. He bequeathed it to Liberty Hall Academy, which afterward became Washington College and is now Washington and Lee University.

He bequeathed his Potomac Company stock (50 shares) to found an institution in the District of Columbia, but, as noted, this became valueless.

I have sought in this essay to bring together facts that will assist in showing that Washington possessed, and in his own day was esteemed for, abilities that are now not often ascribed to him. Of his many merits, none seems to me more striking and more valuable to the newborn nation than his foresight, his early perception of the importance of highways of commerce. His advocacy of engineering constructions was based upon laborious and dangerous journeys, but he was not a mere globe-trotter. He was, through his training as a surveyor, capable of ascertaining, interpreting, and recording all the data necessary to present his plans to those who were to assist in developing them. In the records of the two companies which were formed to improve Virginia waters, we have ample evidence of the great confidence in which he was held by all classes of citizens.

It has been said by Professor McMaster that in spite of all that has been written and spoken about Washington, the world does not know the man.

This has been largely due, as I have said, to the disproportionate brilliancy of certain periods of his life, but an unfortunate tendency to idealize him has been also responsible. The biographers and historians pass over the striking features of his early life, but they record the story that he said that the mosquitos were so bad at Skenesboro' that they bit through the leather of his boots. This story, which might give much pain to those who have formed their ideas of him from the incident reported from his father's orchard, was afterward explained by the statement that he really said that they bit through his stockings above the boots. His career lay too far within the period of scientific activity to be completely subjected to myth-making tendencies. A similar personality two thousand years ago would have been as completely overlaid with legend and folk-lore as are the heroes of the great empires or religions.

It will be the duty of some historian to give us a correct picture of this great man, and when this is done, I feel sure that alongside of Washington the General, and Washington the President, will stand as a shining example, Washington the Engineer.

I desire to acknowledge with thanks the assistance in obtaining materials for this paper rendered by Mr. T. Wilson Hedley, Librarian of the Mercantile Library; Mr. Herbert Friedenwald, formerly in charge of MSS. in Library of Congress, and Dr. C. H. Lincoln, at present in charge; also to Dr. W. J. Campbell for loan of a facsimile of a Washington map, and to The Rosenbach Company for permission to examine the original of the same and reproduce it for publication.

# SOME EXAMPLES OF RECENT MAIN SEWER CONSTRUCTION BY THE CITY OF PHILADELPHIA.

C. H. OTT.

*Read May 14, 1904.*

THE large territory covered by the city of Philadelphia, viz., one hundred and twenty-nine square miles, containing within its boundaries not only a large area closely built up and densely populated, but also a large number of thickly settled areas of a suburban character, together with its topographical and geological characteristics, offers a number of more or less difficult problems in the design and construction of its sewerage systems from engineering, sanitary, and financial standpoints.

Until 1854, the time of the consolidation of the old city of Philadelphia with its varied environs of districts, boroughs, and townships, thereby making the limits and jurisdiction of the city conterminous with the County of Philadelphia, the total length of main sewers (sewers exceeding three feet in diameter) amounted approximately to 18 miles, a considerable portion of which length consisted of short sections of culverts carrying streams under roadway and street embankments.

The total length of branch sewers (sewers of three feet or less in diameter) approximated 19.5 miles, the greater portion of which was laid within the limits of the old city or in the districts immediately adjacent thereto.

From 1855 to the present time the construction of sewers by the city of Philadelphia has been in steady progress under average annual expenditures of $240,000 for main sewers and $230,000 for branch sewers; the culmination of expenditure and of lengths constructed in any one year being reached in 1894, when 19.4 miles of main sewers costing $1,462,000, and 62.9 miles of branch sewers costing $1,141,000, were constructed.

The total length of sewers constructed to January, 1904, amounted to 160.4 miles of mains, involving an expenditure of $12,244,000, and of 729.7 miles of branches, involving an expenditure of $11,088,000.

During the earlier periods of construction, owing partly to the immediate necessities and demands of building interests and operations and partly to the limits of the legislation and application of appropriations, disconnected lengths of main sewers were built depending for outlets upon the nearest available open streams, which in consequence soon became very foul. In numbers of cases such temporary outfalls into streams occurred several miles distant from the point of final outfall into the Delaware River or into the Schuylkill River below Fairmount dam; generally, however, all of these disconnected lengths of main sewers were designed, located, and constructed in harmony with and as a part of the general sewer system of the drainage basins in which they were built.

During the later periods of construction it has been the policy of the Chief Engineer of the City of Philadelphia to close the gaps formed between the various lengths of sewers built in scattered locations, so as to form progressively continuous structures from the permanent outfalls to the head of each drainage basin. In pursuance of this policy a number of large outfall sewers have been constructed in recent years. These outfall sewers generally pass over or through long reaches of river shores or of meadows back of the river banks, and owing to their large cross-sections, the low elevations of the street grades, the shallow depth of street covering and the character of the ground in which they are built, require special design both as to their main body and foundation construction.

Referring again to the geological situation of the city of Philadelphia in connection with the construction of its systems of main and branch sewers now completed, in progress, or projected, and having their outlets into the Delaware River or into the Schuylkill River below Fairmount dam, it is generally found that the materials encountered in the excavation of the sewer trenches, in order, advancing from the outfalls, are as follows: (1) Alluvial deposits, principally silt of various degrees of compactness and depth, in which, in certain locations, bearing-piles ranging from 7 to 70 feet in length are required, to form suitable foundations. (2) Filled ground and loamy material; fine and coarse sand either firm or water-bearing and quick; firm water-bearing gravel often containing a small amount of clay or other binding material and some small boulders. (3) Loam, clay, firm or water-bearing sand or gravel, decomposing mica schist or hard mica schist. (4) Decomposing and hard mica schist, gneissic rocks varied in character, with occasional dikes of syenite.

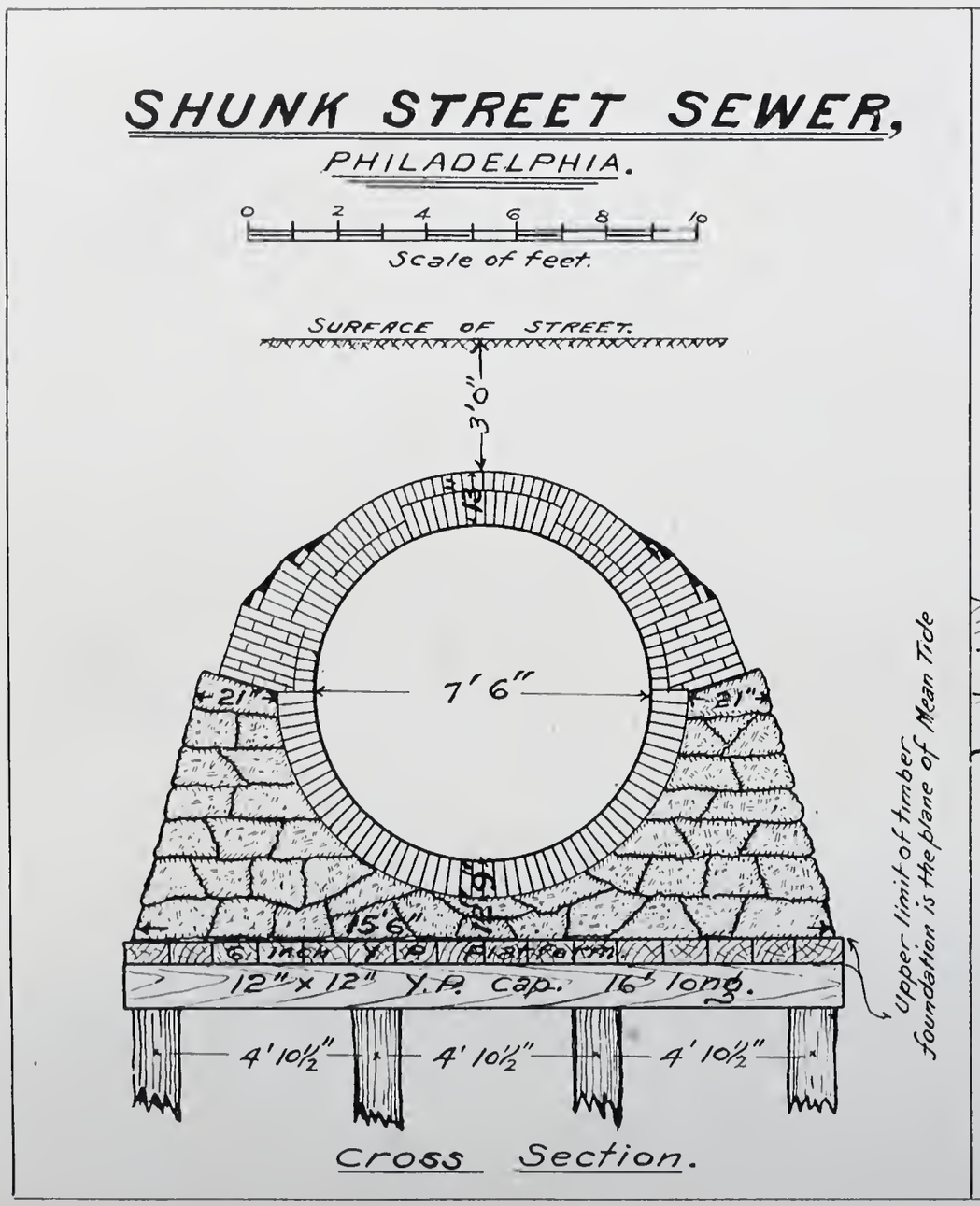

SHUNK STREET SEWER,
PHILADELPHIA.
0 2 4 6 8 10
Scale of feet.
SURFACE OF STREET.
3'0"
13"
7'6"
21"
21"
19"
15'6"
6 inch Y.P. Platform.
12" x 12" Y.P. cap. 16' long.
4'10½"
4'10½"
4'10½"
Upper limit of timber foundation is the plane of Mean Tide
Cross Section.

Fig. 1.

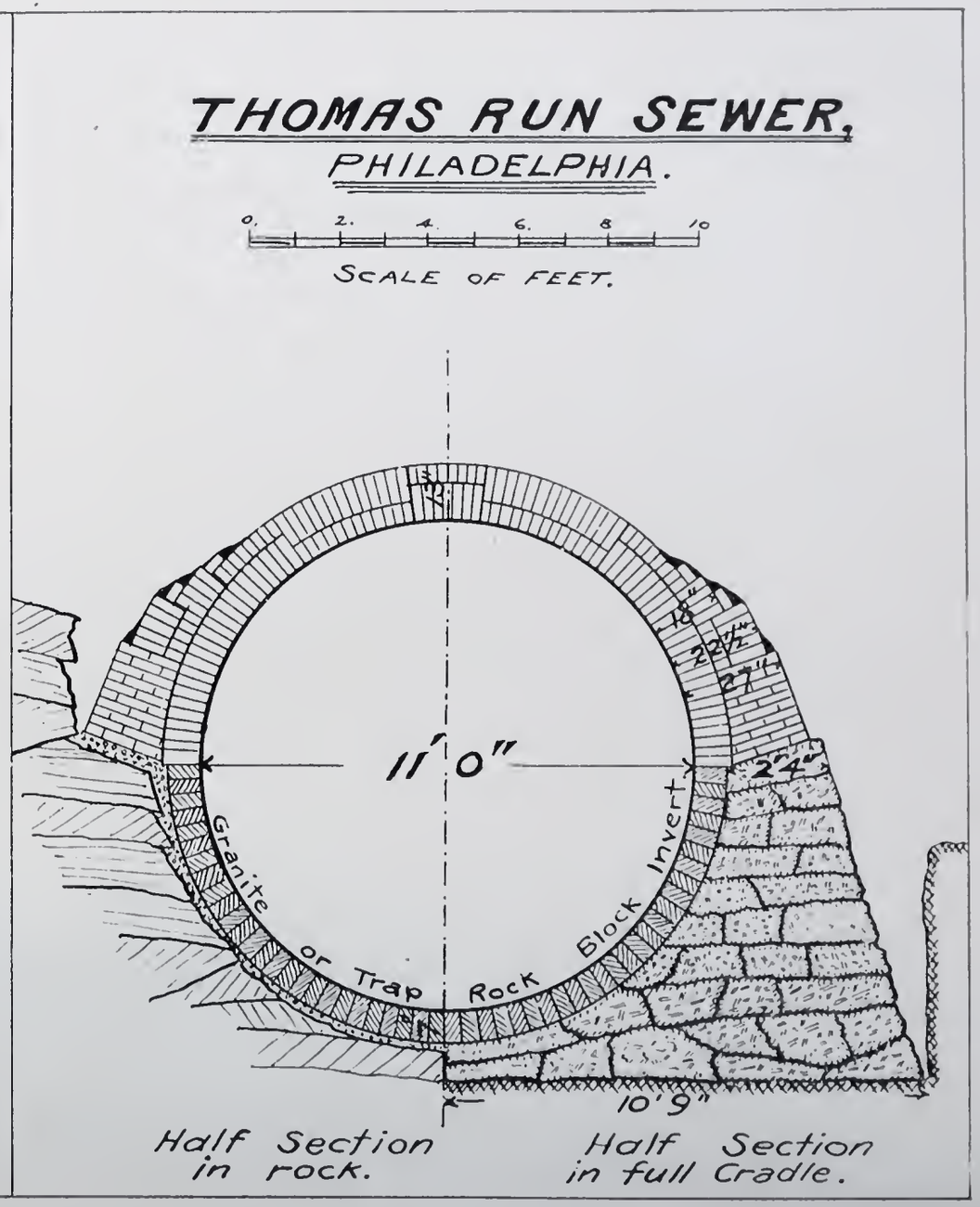

THOMAS RUN SEWER,
PHILADELPHIA.
0. 2. 4. 6. 8 10
SCALE OF FEET.
13"
18"
22½"
27"
11'0"
24"
Granite or Trap Rock Block Invert
10'9"
Half Section in rock.
Half Section in full Cradle.

Fig. 2.

Fig. 3.—Shunk Street Sewer. Separating Chamber at Front and Porter Streets.

The varying character of the materials encountered in the trenches in which the sewers are laid and as outlined in the foregoing, involves the design and construction of foundations and subfoundations as follows:

1. Subfoundations of piles and platform; of platform only and of grillage.
2. Foundations of rubble masonry or concrete cradles.
3. Foundations of the original hard rock shaped as closely as possible to the extrados of the sewer invert; where such material is encountered the entire work is frequently constructed in tunnel if the conditions are suitable.

## Types of Construction.

The Shunk Street sewer system is situated in the southeastern section of the city and will serve a drainage area of about 150 acres.

The construction is typical of that through soft alluvial ground, and consists of a pile and platform foundation, full masonry cradle, and brick invert and arch. The section is circular, 7 feet 6 inches in diameter, and cost, inclusive of the timber foundation, $38.00 per foot. (See Figs. 1 and 3.)

The Swanson Street sewer is situated in the southeastern section of the city and serves a drainage area of 150 acres. This sewer is a rectangular section concrete sewer with I-beam and concrete arch top; on pile and platform foundation. Its section is 5 feet 6 inches vertical by 8 feet horizontal, and cost $46.32 per foot inclusive of the timber foundation. (See Figs. 4 and 5.)

The McKean Street sewer system is also situated in the southeastern section of the city and will serve a drainage area of about 150 acres. A portion of this sewer (1168 feet) is of the reinforced concrete type, the reinforcement being of twisted steel bars, and is built directly upon piles without a timber platform. This sewer is rectangular, 8 feet by 5 feet 6 inches in section, and the roof is partly formed and wholly supported by beams of reinforced concrete. Prior to the construction of this type of sewer, an experimental full-sized section 6 feet in length was built above ground. The roof of this section was loaded with 43,240 pounds of pig-iron supported on a wooden base of four square feet centrally placed on the roof. This load was sustained without any material deflection, deformation, or signs of failure in the section. The cost of this sewer was $42.66 per foot inclusive of the pile foundation. (See Figs. 6 and 7.)

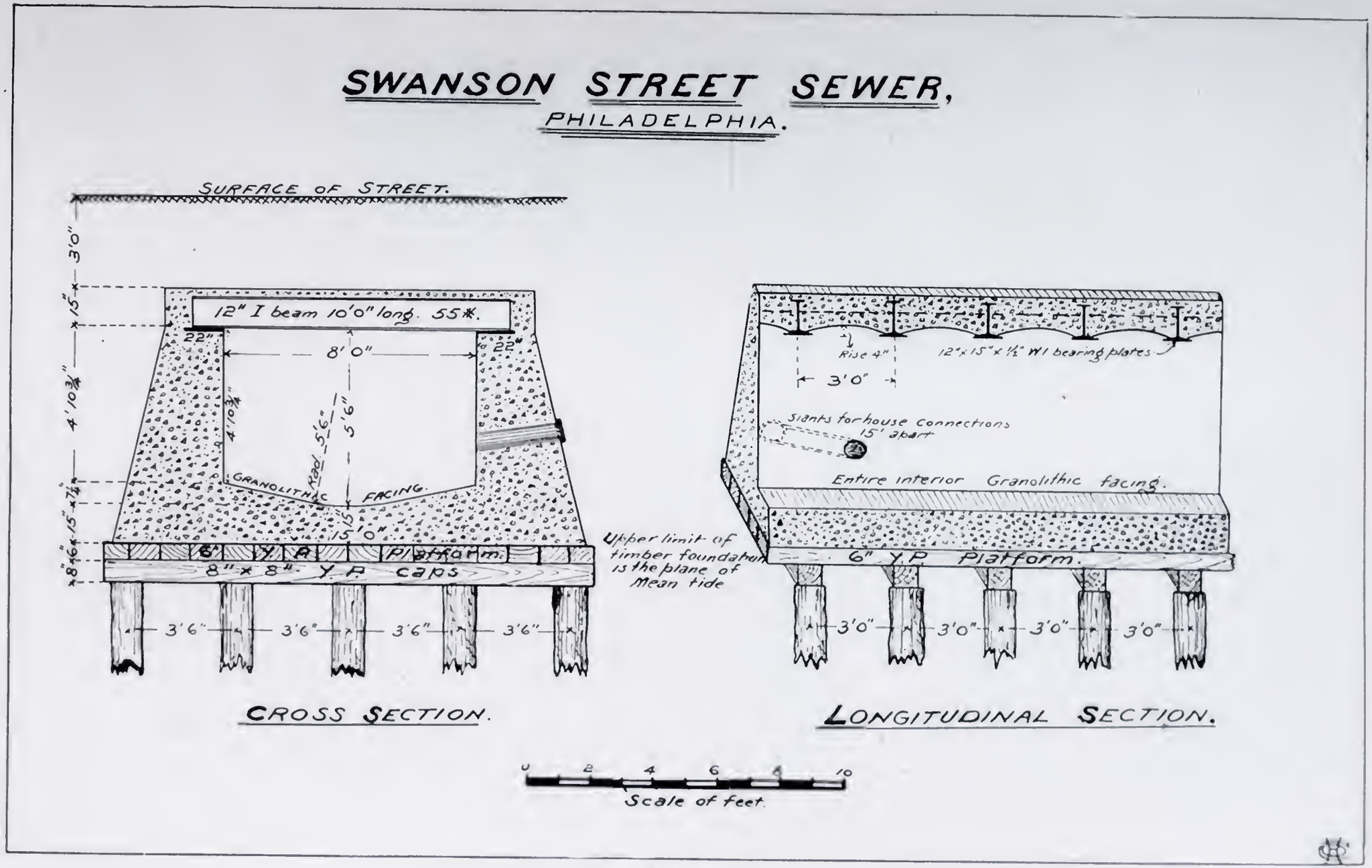

SWANSON STREET SEWER,
PHILADELPHIA.
SURFACE OF STREET.
12" I beam 10'0" long. 55#.
22"
8' 0"
22"
4'10¾"
5'6"
5'6"
GRANOLITHIC FACING.
15' 0"
6" Y.P. Platform.
8" x 8" Y.P. caps
3'6"
3'6"
3'6"
3'6"
3'0"
15"
4'10¾"
7¼"
15"
8"
Upper limit of timber foundation is the plane of Mean tide
CROSS SECTION.
Rise 4"
12" x 15" x ½" W.I. bearing plates
3'0"
Slants for house connections 15' apart
Entire interior Granolithic facing.
6" Y.P. Platform.
3'0"
3'0"
3'0"
3'0"
LONGITUDINAL SECTION.
0 2 4 6 8 10
Scale of feet.

Fig. 4.

Fig. 5.—Concrete Sewer on Swanson Street.

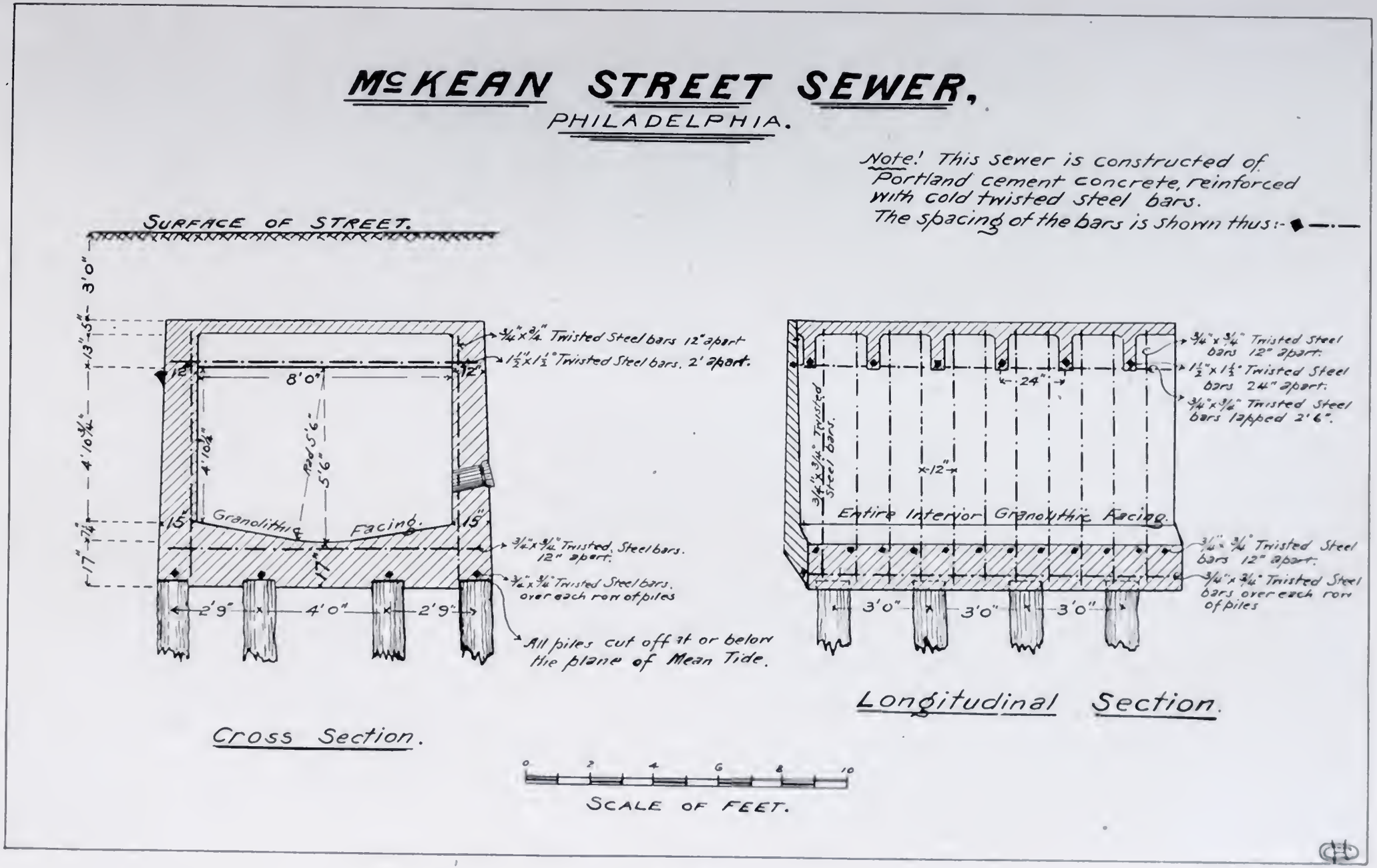

McKEAN STREET SEWER,
PHILADELPHIA.
Note! This sewer is constructed of Portland cement concrete, reinforced with cold twisted steel bars.
The spacing of the bars is shown thus:-
SURFACE OF STREET.
3'0"
5"
13"
4'10¾"
7¼"
17"
12"
8'0"
12"
4'10¾"
Rad 5'6"
5'6"
15"
Granolithic Facing.
15"
17"
2'9"
4'0"
2'9"
¾"x¾" Twisted Steel bars 12" apart
1½"x1½" Twisted Steel bars. 2' apart.
¾"x¾" Twisted Steel bars. 12" apart.
¾"x¾" Twisted Steel bars. over each row of piles
All piles cut off at or below the plane of Mean Tide.
Cross Section.
24"
12"
¾"x¾" Twisted Steel bars.
Entire Interior Granolithic Facing.
3'0"
3'0"
3'0"
¾"x¾" Twisted Steel bars 12" apart.
1½"x1½" Twisted Steel bars 24" apart.
¾"x¾" Twisted Steel bars lapped 2'6".
¾"x¾" Twisted Steel bars 12" apart.
¾"x¾" Twisted Steel bars over each row of piles
Longitudinal Section.
0 2 4 6 8 10
SCALE OF FEET.

Fig. 6.

Fig. 7.—McKean Street Sewer—Invert, Side Walls, and Forms.

The Wakeling Street sewer is situated in Frankford and will serve a drainage area of 2700 acres. At the outfall the sewer is rectangular in section, 16 feet by 10 feet 6 inches in dimensions, and is of concrete throughout with I-beam and concrete arch top. The greater portion of this section built (525 feet) is founded on firm coarse gravel, and on such foundation has cost $59.00 per foot. (See Figs. 8 and 9.)

The Thomas Run sewer system is located in West Philadelphia and is generally founded on rock throughout its entire drainage basin, which embraces 1100 acres. The section is circular throughout and at the outfall is 11 feet in diameter, constructed in full masonry cradle with belgian block invert and brick arch. This section of this sewer cost $28.40 per foot. (See Figs. 2 and 10.)

The Courtland Street sewer is a part of the Wingohocking Creek sewer system, draining a portion of the northern and northwestern section of the city, and serves a drainage area of 4400 acres. At its present outfall it is of an inverted egg-shaped section with a bore equivalent to a circle 17 feet 3 inches in diameter and is constructed in full cradle with belgian block invert and brick arch. This section of sewer cost $56.00 per foot. (See Figs. 11 and 13.)

The George's Run sewer is situated in northern West Philadelphia and serves a drainage area of 232 acres. A portion of this sewer was constructed in tunnel, a section of which with vitrified shale brick invert is shown by Figure 12. The cost of this construction was $20.60 per foot.

The Cohocksink sewer has its outfall at the Laurel Street wharf, Delaware River, and serves a drainage basin of 2500 acres, extending westwardly to Ridge Avenue and Dauphin Street. The greater portion of this sewer system was constructed many years ago and before the general use of cement mortar became customary in culvert or sewer work. A considerable portion of the brick invert of this sewer was laid without any mortar in two-ring rowlock bond, and the arch was laid in lime mortar of a fair quality. Failures of this ancient sewer have occurred from time to time from the following causes: (1) Insufficient cradle foundations; (2) the tearing out of the rowlock brick courses of the invert by the great volume and velocity of flood discharges; (3) the wearing away of the invert by the constant flow, charged in rainy weather with a considerable quantity of gritty matter; (4) in several instances the bursting by surcharge during excessive rainfalls coincident with high tides. The reconstruction of the defective portions of this sewer has been in active progress during the past

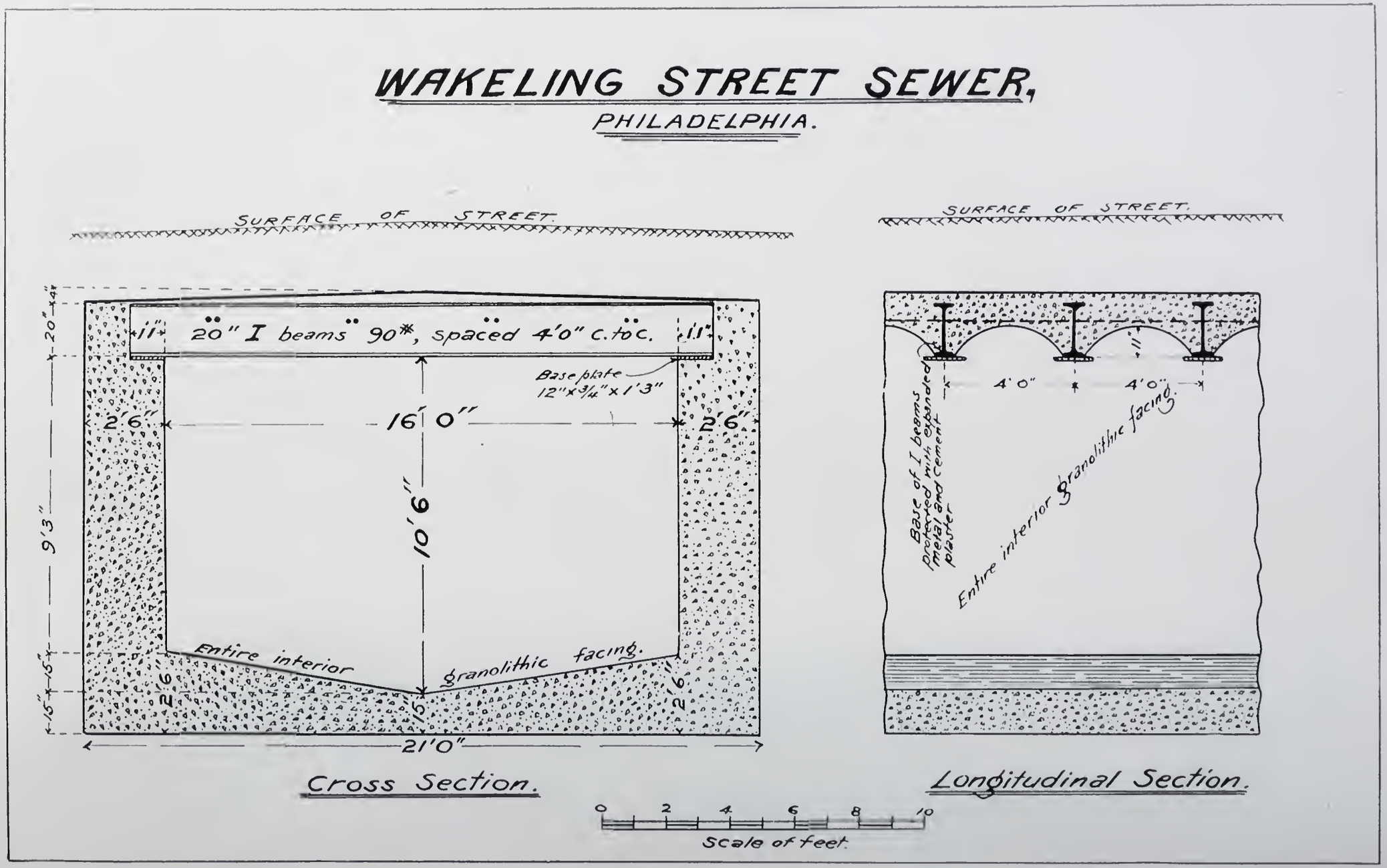

WAKELING STREET SEWER,
PHILADELPHIA.
SURFACE OF STREET.
20" I beams 90#, spaced 4'0" c. to c.
1'1"
1'1"
Base plate 12"x3/4"x1'3"
2'6"
16'0"
2'6"
10'6"
9'3"
20"
4"
15"
15"
Entire interior granolithic facing.
2'6"
15"
2'6"
21'0"
Cross Section.
SURFACE OF STREET.
Base of I beams protected with expanded metal and cement plaster
4'0"
4'0"
Entire interior granolithic facing.
Longitudinal Section.
0 2 4 6 8 10
Scale of feet.

Fig. 8.

Fig. 9.—Wakeling Street Sewer.

Fig. 10.—Thomas Run Sewer.

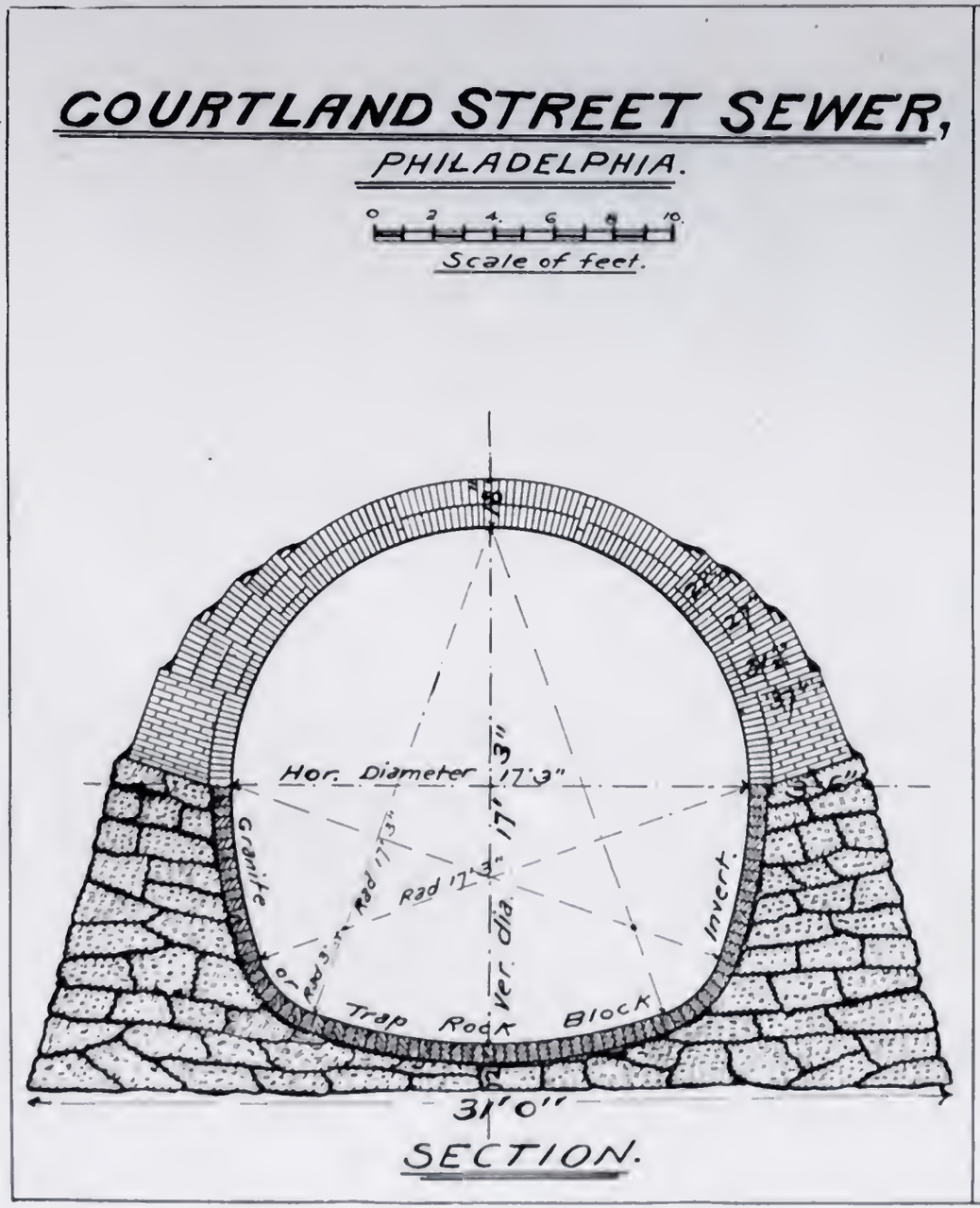

COURTLAND STREET SEWER,
PHILADELPHIA.
0 2 4 6 8 10
Scale of feet.
Hor. Diameter 17'3"
Rad 17'3"
Ver. dia. 17'3"
Granite
Invert.
Trap Rock Block
31'0"
SECTION.

Fig. 11.

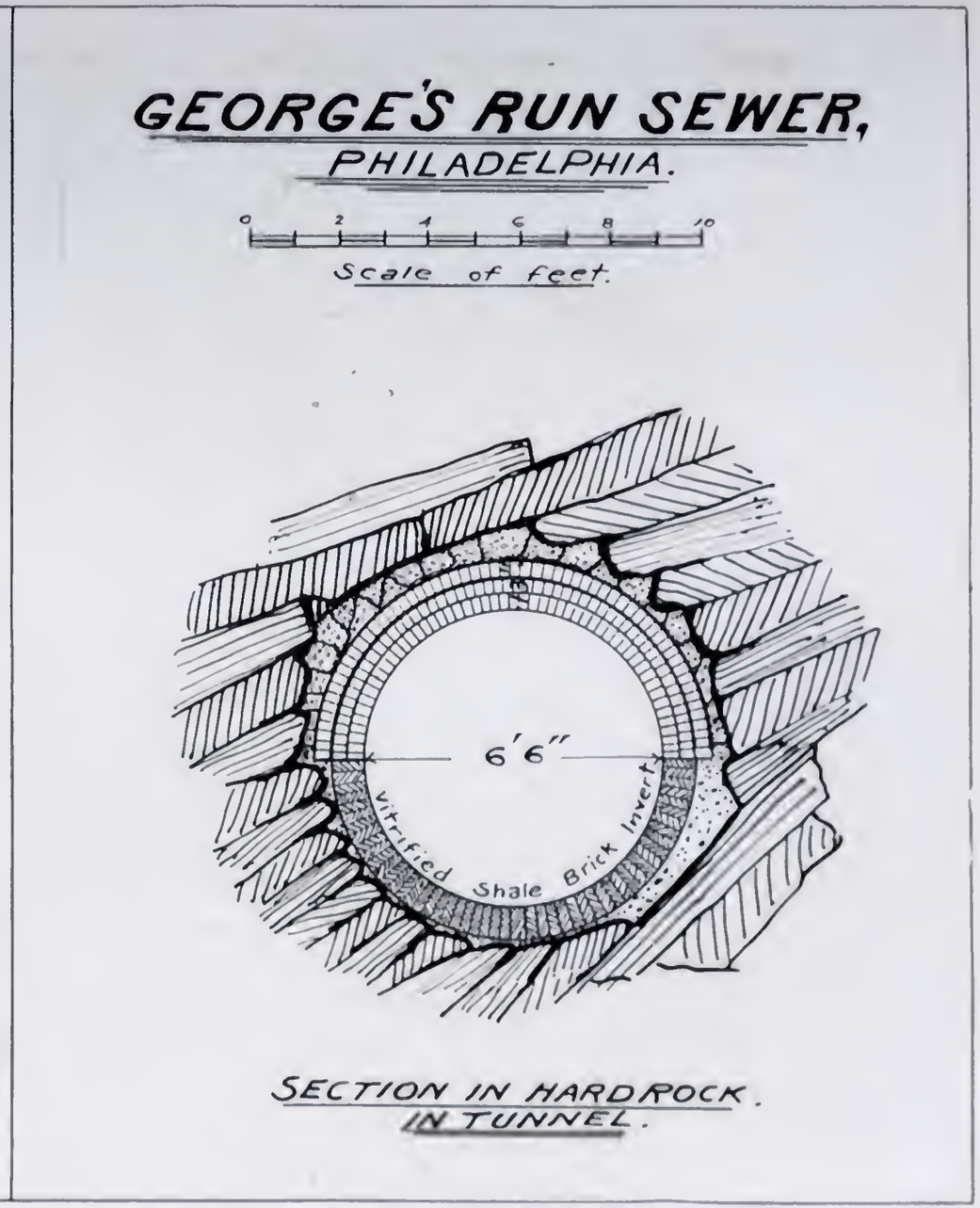

GEORGE'S RUN SEWER,
PHILADELPHIA.
0 2 4 6 8 10
Scale of feet.
6'6"
Vitrified Shale Brick Invert
SECTION IN HARDROCK.
IN TUNNEL.

Fig. 12.

Fig. 13.—Courtland Street Sewer.

Fig. 14.—Cohocksink Sewer, Separating Chamber at Ninth and Berks Streets.

ten years and it is the plan of the Bureau of Surveys to continue this reconstruction until all defective portions of this sewer system are replaced by modern work. The surcharge of this sewer has also been relieved by the construction of two relief sewers, one of which was completed some years ago, the other having just been completed. There has never been a break in those portions of this sewer which have been reconstructed during the past ten years under modern methods. The cost of the reconstruction has varied from $45.00 to $90.00 per foot, depending upon the depth of the excavation. (See Fig. 14.)

## DISCUSSION.

George S. Webster.—In some of the old sewers which have caused trouble in the city of Philadelphia it has been found upon investigation that the brick inverts were partly or wholly worn out; this was especially true where the velocities were great and where gravel or other heavy material had entered the sewer. To avoid this, in modern construction the inverts of brick sewers having high velocities are built with granite or trap rock blocks. Where the velocity of the sewer when running full will be less than 12 feet per second, and more than 8 feet per second, vitrified shale bricks are used, and for velocities lower than 8 feet per second the inverts are formed of hard-burned clay bricks.

In designing sewers the following table has been adopted, giving the gradients for the determination of the materials to be used in sewer inverts.

At a number of places in the old Cohocksink sewer, which is 13 feet in diameter, the bottom was found to have been completely carried away. The ordinary flow amounts to about 2 feet in depth. In making examinations, inspectors, walking through the sewer with a safety line, would at points suddenly drop into holes two or three feet deep, showing that the whole foundation had washed out, leaving the arch with but little support.

All large sewers built in recent years have been founded in masonry or concrete cradles.

Mr. Ott.—All of the rectangular section sewers shown were built where they will have very shallow depths of covering. The construction of the ordinary brick arch type was prohibitory. The departure from the circular or approximately circular form is only warranted by such conditions of location, inasmuch as the prices bid for circular brick sewers have been somewhat less than those bid for rectangular section concrete sewers, with or without reinforcement, the conditions of risk, excavations, foundations, and duties being equal. Generally the rectangular section is not desirable for a sewer of variable flow.

Wm. Easby, Jr.—Have any systematic sewer gaugings been made in the city of Philadelphia; and if so, are they published?

Mr. Webster.—There have been established six pluviometer stations, widely distributed over the area of the city, where delicate automatic recording instruments, giving the amount and the intensity of the rainfall, are maintained. There have also been established five sewer gauging stations contain-

ing self-recording instruments. The velocity of the flow in the sewers is frequently determined by means of velocity meters. This work has just been systematically commenced, but is not yet fully inaugurated. Some of the results will appear in the Annual Report of the Bureau of Surveys, which will be issued in June.

F. Schumann.—Is any data existing as to the comparative cost of the concrete compared with the circular or arched sewer?

Mr. Ott.—The first section of the McKean Street sewer, rectangular in section, 8 feet by 5 feet 6 inches, was built on pile and platform foundation,

## TABLES OF GRADIENTS FOR THE DETERMINATION OF THE MATERIALS TO BE USED IN SEWER INVERTS.

### Tables for Circular Sewers.

| Vitrified Shale Brick Invert to Springing Line to be used in all Cases where Gradients are More Than : | | Stone Block Invert to Springing Line to be Used in all Cases where Gradients are More Than : | |
|---|---|---|---|
| Diameter. | Grade Per 100 Feet. | Diameter. | Grade Per 100 Feet. |
| 3 feet 0 inches | 1.000 feet | 3 feet 0 inches | 2.207 feet |
| 3 feet 6 inches | 0.788 feet | 3 feet 6 inches | 1.782 feet |
| 4 feet 0 inches | 0.652 feet | 4 feet 0 inches | 1.466 feet |
| 4 feet 6 inches | 0.553 feet | 4 feet 6 inches | 1.244 feet |
| 5 feet 0 inches | 0.478 feet | 5 feet 0 inches | 1.076 feet |
| 5 feet 6 inches | 0.420 feet | 5 feet 6 inches | 0.944 feet |
| 6 feet 0 inches | 0.373 feet | 6 feet 0 inches | 0.839 feet |
| 6 feet 6 inches | 0.335 feet | 6 feet 6 inches | 0.753 feet |
| 7 feet 0 inches | 0.303 feet | 7 feet 0 inches | 0.682 feet |
| 7 feet 6 inches | 0.277 feet | 7 feet 6 inches | 0.623 feet |
| 8 feet 0 inches | 0.254 feet | 8 feet 0 inches | 0.572 feet |
| 8 feet 6 inches | 0.234 feet | 8 feet 6 inches | 0.527 feet |
| 9 feet 0 inches | 0.217 feet | 9 feet 0 inches | 0.489 feet |
| 9 feet 6 inches | 0.203 feet | 9 feet 6 inches | 0.456 feet |
| 10 feet 0 inches | 0.190 feet | 10 feet 0 inches | 0.427 feet |
| 10 feet 6 inches | 0.178 feet | 10 feet 6 inches | 0.401 feet |
| 11 feet 0 inches | 0.168 feet | 11 feet 0 inches | 0.378 feet |
| 11 feet 6 inches | 0.158 feet | 11 feet 6 inches | 0.356 feet |
| 12 feet 0 inches | 0.150 feet | 12 feet 0 inches | 0.338 feet |
| 12 feet 6 inches | 0.142 feet | 12 feet 6 inches | 0.320 feet |
| 13 feet 0 inches | 0.135 feet | 13 feet 0 inches | 0.305 feet |
| 13 feet 6 inches | 0.129 feet | 13 feet 6 inches | 0.291 feet |
| 14 feet 0 inches | 0.123 feet | 14 feet 0 inches | 0.278 feet |
| 14 feet 6 inches | 0.118 feet | 14 feet 6 inches | 0.265 feet |
| 15 feet 0 inches | 0.113 feet | 15 feet 0 inches | 0.254 feet |
| 15 feet 6 inches | 0.108 feet | 15 feet 6 inches | 0.244 feet |
| 16 feet 0 inches | 0.104 feet | 16 feet 0 inches | 0.235 feet |
| 17 feet 0 inches | 0.097 feet | 17 feet 0 inches | 0.218 feet |

Note.—These gradients are figured for a mean velocity of 8 feet per second running full or half full. When running 0.3 full, velocity = 6.24 feet per second.

Note.—These gradients are figured for a mean velocity of 12 feet per second running full or half full. When running 0.3 full, velocity = 9.36 feet per second.

TABLES FOR EGG-SHAPED SEWERS.

| Vitrified Shale Brick Invert (See Std. Details) to be Used in all Cases where Gradients are More Than: | | Stone Block Invert (See Std. Details) to be Used in all Cases where Gradients are More Than: | |
|---|---|---|---|
| Diameters. | Grade Per 100 Feet | Diameters. | Grade Per 100 Feet |
| 2 feet 3 inches × 1 foot 6 inches | 2.40 feet | 2 feet 3 inches × 1 foot 6 inches | 5.40 feet |
| 2 feet 6 inches × 1 foot 8 inches | 2.00 feet | 2 feet 6 inches × 1 foot 8 inches | 4.50 feet |
| 3 feet 0 inches × 2 feet 0 inches | 1.75 feet | 3 feet 0 inches × 2 feet 0 inches | 4.00 feet |
| 3 feet 3 inches × 2 feet 2 inches | 1.40 feet | 3 feet 3 inches × 2 feet 2 inches | 3.00 feet |
| 3 feet 6 inches × 2 feet 4 inches | 1.25 feet | 3 feet 6 inches × 2 feet 4 inches | 2.75 feet |
| 4 feet 0 inches × 2 feet 8 inches | 1.00 feet | 4 feet 0 inches × 2 feet 8 inches | 2.30 feet |
| 4 feet 6 inches × 3 feet 0 inches | 0.85 feet | 4 feet 6 inches × 3 feet 0 inches | 2.00 feet |

NOTE.—These gradients are figured for a mean velocity of 8.32 feet per second running full or half full. When running 0.3 full, velocity = 6.24 feet per second.

NOTE.—These gradients are figured for a mean velocity of 12.48 feet per second running full or half full. When running 0.3 full, velocity = 9.36 feet per second.

side walls and invert of concrete not reinforced, top of I-beams and concrete arches, and cost inclusive of the timber foundation $46.32 per linear foot. A continuation of the same sewer of the same section, but built of reinforced concrete on pile foundation, cost $42.66 per linear foot, inclusive of the pile foundation. The work was done by different contractors and is in favor of the reinforced concrete construction at the rate of $3.66 per linear foot. The continuation of the reinforced concrete sewer without timber foundation cost $32.00 per linear foot, and a circular brick sewer having the same capacity and duty, being a continuation of the rectangular reinforced concrete section, all the surrounding conditions being equal, cost $24.90 per linear foot. The work was done by different contractors and is in favor of the brick circular sewer at the rate of $7.10 per linear foot.

# NOTES ON LUTES AND CEMENTS.

SAMUEL S. SADTLER.

*Read June 4, 1904.*

In a recent paper read by me before the Chemical Section of the Franklin Institute I treated in a general way of the subject of lutes and gave some examples under the following heads: (1) Plaster of Paris; (2) hydraulic cement; (3) clay; (4) lime; (5) asphalt and pitch; (6) resin; (7) rubber; (8) linseed oil; (9) casein and albumen; (10) silicate of soda and chloride cements; (11) flour and starch; (12) miscellaneous.

When asked to read a paper before this Club, I thought it might be of interest to treat of certain kinds of lutes and cements most likely to be used by engineers and arranged according to the intended application.

I have taken up this subject, not because there was little to be found in the literature, but because what is recorded is not very dependable and is, in most cases, vouched for by no one. It seems to be copied and abstracted from one source to another until no one would be willing to assume the authorship. A great many of the formulæ given n encyclopedic works show that the authors were ignorant of the nature of the ingredients they used. Many formulæ are impossible, having incompatibles from a chemical standpoint, a mistake that young doctors sometimes make in their prescriptions; then many are of foreign origin and the use of grain alcohol is referred to as if it were as cheap as petroleum-naphtha; or potato-starch is used where we would use corn-starch for economy. The great bulk of them are very inferior in usefulness and a limited number are impracticable. It has been my endeavor to pick out some of the best.

With regard to the literature on this subject, a great deal of information may be had in the formula books, such as those of Spon, Wahl and Brannt, a long article in Muspratt's "Handwörterbuch der Chemie," and similar places. The engineering hand-books are practically barren of any information on this subject.

I have had such repeated occasion to use luting and cementing materials for various purposes in the laboratory and works that I thought some condensed information on the subject might benefit others if brought together.

They may be classified as follows:

1. Water- and steam-proof.
2. Oil-proof.
3. Acid-proof.
4. Proof to hydrocarbon gases.
5. Chlorine-proof.
6. Elastic.
7. General purposes.
8. Marine glue.
9. Gaskets.
10. Machinists'.
11. Leather (belting).
12. Crucible, iron, and stone.
13. Core compounds.
14. Briquetting.

1. *Water-Proof Compositions.*—Of use to engineers are the asphalt fluid coatings for reservoir walls, concrete foundations, brick, wood, etc.

Asphalt only partly dissolves in petroleum naphtha, but heated in a steam-jacketed kettle and not thinned out too much, a mixture of the two may be obtained in which the part of the asphalt not dissolved is held in suspension. Asphalt is entirely soluble in benzol or toluol, which are about the cheapest solvents for all the constituents of asphalt. Tar and pitch are sometimes used in this connection, but tar contains water, light oils, and free carbon, and does not wear as well as good refined asphalt; and pitch contains free carbon, which is sometimes objectionable when thinned out with a solvent. The asphalt alone is somewhat pervious to water, and this is improved by adding about one-fourth its weight of paraffin, and made better if in addition a little boiled linseed oil is added also. For thicker compositions, where body is required, asbestos, stone powder, cement, etc., may be added as fillers.

Lutes of linseed oil thickened with clay, asbestos, red or white lead, etc., are water-proof if made thick enough. These are much used for steam joints.

Flaxseed meal made into a paste with water is often serviceable, the oil contained serving as a binder as the water evaporates.

2. *Oil-Proof.*—The most useful lute for small leaks, etc., is the well-known "hektograph composition," as follows:

| | |
|---|---|
| Good glue or gelatin, | 2 parts. |
| Glycerin, | 1 part. |
| Water, | 7 parts. |

This is applied warm and stiffens quickly on cooling. Another very useful composition is a stiff paste of molasses and flour. Another preparation impervious to oil vapors is the "flaxseed poultice," mentioned in Sec. 1, which is proof to oil vapors.

One of the strongest cements, and one which is really oil-proof, water-proof, acid-proof, and proof to almost everything, is a stiff paste of glycerin and litharge. These form a chemical combination and set in a few minutes. If a little water is added, it sets more slowly, which is often an advantage. It is mixed when required for use. Plaster of Paris wetted, by itself, or mixed with asbestos, straw, hair, etc., is useful. A solution of silicate of soda made into a stiff paste with carbonate of lime, gets hard in six to eight hours.

3. *Acid-Proof.*—The asphalt compositions already mentioned, compositions of melted sulphur with fillers of stone powder, cement, sand, etc.; also the following, which withstands hydrochloric acid vapors:

| | | |
|---|---|---|
| Rosin, | 1 | part. |
| Sulphur, | 1 | " |
| Fire clay, | 2 | parts. |

The lute composed of boiled linseed oil and fire-clay acts well with most acid vapors. The composition of glycerin and litharge referred to is useful in this connection, especially when made up according to the formula of Geo. E. Davis, viz.:

| | | |
|---|---|---|
| Litharge, | 80 | pounds. |
| Red lead, | 8 | " |
| "Flock" asbestos, | 10 | " |

fed into a mixer, a little at a time, with small quantities of boiled oil (about six quarts of oil being used). Sockets joined in 3-inch pipes carrying nitric acid were caulked with this and showed no leaks in nine months.

A particularly useful cement for withstanding acid vapors, being also tough and elastic, is:

| | | |
|---|---|---|
| Crude rubber, cut fine, | 1 | part. |
| Linseed oil, boiled, | 4 | parts. |
| Fire-clay, | 6 | " |

The rubber is dissolved in carbon disulphide to the consistency of molasses and then mixed with the oil. Other examples of acid-proof cements, taken from "A Handbook of Chemical Engineering," by Geo. E. Davis, and vouched for by the author, who has used them in chemical engineering work, are as follows:

"Black putty," made by intimately mixing equal portions of china-clay, gas-tar, and linseed oil. The china-clay must be well dried by putting over a boiler, etc. The author says that it is probable that anthracene oil might be used to advantage instead of gas-tar, for reasons which I stated in referring to asphalt lutes. It seems to me, however, that soft pitch or, better still, a semi-liquid asphalt or naphtha would be best.

Barytes cement is composed of pure, finely ground sulphate of barium, and is made into a putty with a solution of silicate of soda. This sets very hard when moderately heated, and is then proof against acids. Mr. F. E. Dodge has tried this and finds the gravity of the silicate of soda should be between 1.2 and 1.4, 24° to 42° Beaumé. If too thin, it does not hold; and when thicker than 1.4, it expands and breaks.

4. *Hydrocarbon Gases.*—Compositions of plaster and cement, the former setting more quickly, are used. Also compositions of casein, such as:

| | |
|---|---|
| Finely powdered casein, | 2 parts. |
| Fresh slaked lime, | 50 " |
| Fine sand, | 50 " |

Water is added, when used, to form a thick mush.

Various mixtures of silicate of soda are employed in which the thick silicate is absorbed in some inert material, as clay, sand or asbestos.

5. *Chlorine.*—The best and only reliable compositions are a few made with Portland cement, and the following is much used for electrolytic and chemical plants:

| | |
|---|---|
| Powdered glass, | 1 part. |
| Portland cement, | 1 " |
| Silicate of soda, | 1 " |
| A small amount of powdered slate. | |

This lute is said to stand acid and alkali, as well as the influences of chlorine. Linseed oil made into a paste with fire-clay serves for a time.

6. *Elastic Cements.*—The various cements containing rubber are elastic, if it is in predominating amount; many containing boiled linseed oil and the hectograph composition already mentioned are quite elastic. The rubber-linseed oil cement, given under Sec. 3, is very tough and useful for nearly all purposes except when oil vapors are to be confined. The most useful single rubber lute is probably the so-called Hart's india-rubber cement. Equal parts of raw linseed

oil and pure masticated rubber are digested together by heating and this mixture made into a stiff putty with fine "paper stock" asbestos. I have found it more convenient, however, to dissolve the rubber, first in carbon disulphide, and after mixing the oil with it, to let the solvent evaporate spontaneously.

7. *General Purposes.*—One of the most useful is plaster of Paris, and especially when mixed with asbestos, straw, flush trimmings, hair, broken stone, etc., used according to temperature, strain, and other conditions. A putty of flour and molasses is a good composition to keep in a works ready for quick application when needed. It serves almost any purpose at moderate temperatures for a time. Casein compositions have great strength.

White of egg made into a paste with slaked lime is strong and efficient, but must be used promptly on account of its quick setting qualities.

8. *Marine Glue.*—This can be purchased almost as cheaply as made. The rubber must first be dissolved in carbon disulphide or turpentine before mixing with the heated combination of the other two ingredients. Its uses are well known.

| | |
|---|---|
| Crude rubber, | 1 part. |
| Shellac, | 2 parts. |
| Pitch, | 3 " |

9. *Gasket Compositions.*—Of course, almost any cementing substance may be used with rings of asbestos, etc., for gaskets, but there are some that I have used and which I have known others to choose especially for that purpose.

With regard to asphalt, tar, pitch and petroleum residuum, I would recommend soft or hard pitch, as may be desired, because there are no light oils or water to go off at low heats, and the free carbon and compounds very high in carbon are good fillers to asbestos gaskets at high temperatures. Silicate of soda by itself is much used, but is sometimes advantageously mixed with casein, fine sand, clay, asbestos, carbonate of lime, caustic lime, magnesia, oxides of heavy metals, such as lead, zinc, and iron, and powdered barytes. A few that might be selected are—silicate of soda and asbestos; silicate of soda, asbestos and slaked lime; silicate of soda and fine sand; silicate of soda and fire-clay.

10. *Machinists' Cements.*—These are the well-known red and white leads. The red lead is often diluted with an equal bulk of silica or

other inert substance so as to make it less powdery. The best way that I have found to do this, however, is to add rubber or gutta-percha to the oil as follows:

| | |
|---|---|
| Linseed oil, | 6 parts by weight. |
| Rubber or gutta-percha, | 1 part " " |

The rubber or gutta-percha is dissolved in sufficient carbon disulphide to give it the consistency of molasses, mixed with the oil, and left exposed to the air for about twenty-four hours. The red lead is then mixed to a putty. Oxide of iron makes a less brittle cement than red lead. Probably fish oils and red lead would make good lutes of the class for joining pipes, as the fish oils are not such strong drying oils as linseed, and their use might be a case of permissible substitution rather than adulteration.

11. *Leather Cements.*—(For leather belting.) This subject is treated fully and well in the literature, and I only quote some formulæ for the convenience of the readers of this paper. Those I select seem to be the cheapest, and from a knowledge of the chemistry of the subject, the best. The following formulæ are given in the "Papier Zeitung," vol. 18, p. 2618. "(1) Equal parts of good hide glue and American isinglass, softened in water for ten hours and then boiled with pure tannin until the whole mass is sticky. The surface of the joint should be roughened and the cement applied hot. (2) One kilo of finely shredded gutta-percha digested over a water-bath with 10 kilos of benzol, until dissolved, and 12 kilos of linseed oil varnish stirred in. (3) Seven and one-half kilos of finely shredded india-rubber are completely dissolved in 10 kilos of carbon disulphide by treating whilst hot, 1 kilo of shellac and 1 kilo of turpentine are added, and the hot solution heated until the two latter ingredients are also dissolved."

Another one noticed in the "Journal of the Society of Chemical Industry" seems to be good:

| | |
|---|---|
| Gutta-percha, | 8 ozs. |
| Pitch, | 1 oz. |
| Shellac, | 1 " |
| Sweet oil, | 1 " |

These are melted together.

A formula from Spon's "Dictionary of Workshop Receipts" is about as follows: Fish glue is soaked in water twenty-four hours, allowed to drain for a like period, boiled well and a previously melted

mixture of 2 ounces of rosin and ½ ounce of boiled oil is added to every 2 pounds of glue solution.

I have not verified any of these formulæ for leather cements.

12. *So-called Iron, Stone, and Crucible Cements.*—These are all hard, stone-like compositions. The oxychloride cements, consisting essentially of oxychlorides of magnesium and zinc, are very hard and are much used in engineering construction.

*Stone cements:* Two formulæ which I gave in my previous paper, are:

| | |
|---|---|
| Zinc oxide or magnesium oxide, | 2 parts. |
| Zinc or magnesium chloride, | 1 part. |
| Water to make a paste. | |

When dry, these become very hard and strong. Powdered stone is generally used as a diluent.

*Iron cements:* When iron in a fine state of division, as in fresh filings or cast-iron borings that have been powdered, is mixed with an oxidizing agent, such as manganese dioxide or a substance electro-negative to iron, such as sulphur, in a good conducting solution like salt or salammoniac, galvanic action sets in very rapidly, and the iron swells, by forming iron oxide, and cements the mass together. It is best diluted with Portland cement. A formula which I give from memory is:

| | |
|---|---|
| Iron filings, | 40 parts. |
| Manganese dioxide, or flowers of sulphur, | 10 " |
| Salammoniac, | 1 part. |
| Portland cement, | 20 to 40 parts. |
| Water to form a paste. | |

These cements are used extensively in foundries, etc.

*Crucible cements:* Mixtures of clay and borax in which the clay predominates. Silicate of soda and powdered glass or sand are the best known compounds for cementing lids on crucibles, etc. Sometimes the "iron cements" are used for such purposes, or iron filings and a little manganese dioxide are added to the above compositions for crucible cements.

13 and 14. *Core Compounds and Briquetting.*—These may be treated together, as their actions are closely analogous. Some of the substances used for briquettes are: Dextrin, spoiled potatoes, grain and starchy materials, molasses, glucose, clay, sand, loams, bituminous coal, pitch, asphalt and tar, Oxychloride cement and Portland cement.

Most of these have also been used as core compounds, those most

advantageously employed being probably flour, or meal of some kind, dextrin and molasses.

Briquetting requires more of a binder than is necessary for cores, and the evolution of gas is not so important; in fact, some briquette compositions use enough binder to supply carbon and reducing gases to effect a reduction of the oxides of the ore.

There are cements for various miscellaneous purposes, but the most important uses of interest to engineers have been briefly treated in this paper. A limited number, if carefully selected, would be found to answer all requirements, and it is often desirable to have a few prepared that can be used on short notice.

## DISCUSSION.

E. M. Nichols.—Could fish oil be used in ordinary steam-fitting, in connection with red lead or linseed oil?

Mr. Sadtler.—Yes; it has recently occurred to me that an oil with milder drying properties than linseed might be better. Corn oil might be good for the purpose. Linseed oil gets brittle and powdery with red lead, as is noticeable when the pipes are taken apart.

Mr. Nichols.—My experience with cements used for steam fitting is that the more quickly they dry, the more perfectly they fill up any imperfections that exist in the thread of the pipe or of the fittings, and we do not desire as elastic material. There is also another purpose, as a lubricant, which will enable the workman to screw the pipe into the fitting much easier than would be done if it was not there. If the fittings and pipe are fairly accurate, plumbago and linseed oil will prove very satisfactory, although some engineers specify nothing but red lead and oil.

# THE DIESEL ENGINE IN PRACTICE.

JAMES D. MACPHERSON.

*Read June 4, 1904.*

THIS paper is intended to convey a fair estimate of this form of internal combustion engine, as it now is, in the hands of American engineers. The theoretical side will be lightly touched on, as the practical operation has proved the accuracy of conception and calculation. The paper will be divided into the following sections:

1. Cycle of operation.
2. Types of engines: single, double, triple and quadruple.
3. General features of design.
4. Regulation.

## CYCLE OF OPERATION.

The engine operates on what is commonly known as the Otto or four-stroke cycle; that is to say, the cycle of operations in one cylinder is completed in four strokes, as follows:

First: Downward (or outward, if horizontal) aspiration stroke. In this stroke the piston moves to the outward or bottom end of the cylinder, and at the same time, either by suction or mechanically, the air admission valve opens and allows the cylinder to fill with fresh air at atmospheric pressure. The air is somewhat heated in passage through the valves and port, hence, when the end of the stroke is completed, it is somewhat below atmospheric density and a little higher in temperature, but this difference has little effect on the results obtained.

Second: Upward (or inward) stroke compression. During this stroke, the air is compressed to a pressure of 500 pounds per square inch, at which pressure it has sufficient temperature to ignite any form of petroleum (crude or refined) spontaneously. There are no valves open during this stroke, and there is nothing in the cylinder but pure air.

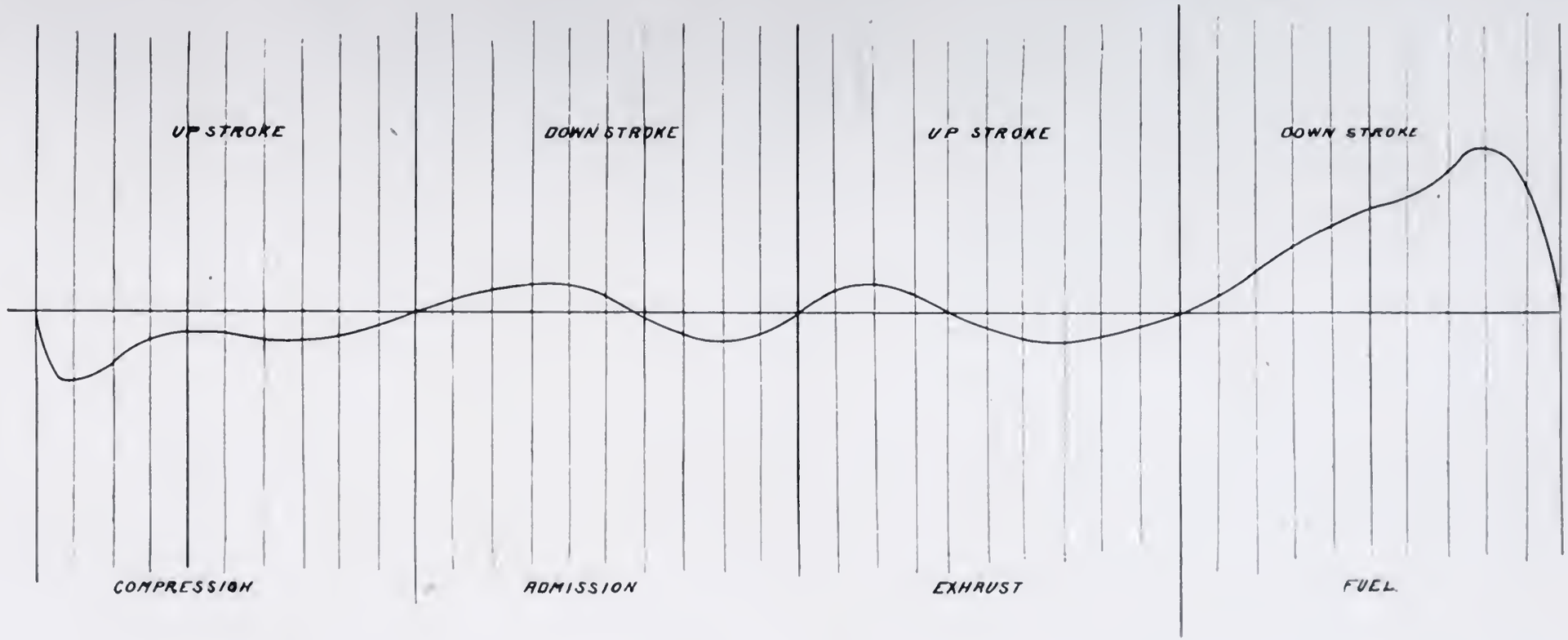
The volume of compression space is all embodied in the cylinder head and is first found by calculation. A wooden pattern is then made and whittled until its weight agrees with the calculated volume. Then a plaster-of-Paris core box is made, and this is used to make the cores for all similar heads.

Third: When the piston has reached the top of the compression stroke and the crank is just crossing the dead center, a small needle valve, called the fuel valve (placed on side of cylinder at one end of the port, in which the other valves open), opens, and a mixture of fuel and compressed air is blown into the already red-hot air in the cylinder. The quantity of fuel is not all blown in at once; instead, the fuel injection is maintained for a period equal to 10 per cent. of the downward stroke of the piston. It is possible to do this with the small quantity of petroleum necessary, by reason of the mixture with compressed air, which increases the volume and thus gives a quantity whose ejection can be controlled. The compressed air referred to is compressed by an independent two-stage compressor to 800 pounds per square inch, and cooled before introduction to the fuel valve.

During this period the intention is to maintain the temperature in the engine cylinder nearly constant, allowing the pressure to fall in conformity with the laws of expansion at constant temperature. It is apparent that this can only be attained at or near the normal load of the engine. With an overload, the temperature will rise somewhat, and with a light load it must fall, as the quantity of fuel injected is not sufficient to add the heat lost in expansion of the large quantity of air in the cylinder.

After the needle valve closes, the hot gases expand until the piston has traveled 90 per cent. of its stroke, when the exhaust valve opens, to relieve the pressure, before commencement of the next upward or exhaust stroke. The pressure at opening of the exhaust valve for normal load is generally 35 pounds per square inch and the temperature about 700° F.

Fourth: This fourth and last stroke of the cycle takes place with the piston traveling upward, the exhaust valve open, and the hot gases rushing out through the valve and port. When the piston reaches the top center, the exhaust valve closes, the admission valve begins to open, and the whole series of operations is repeated.




EFFORTS ON CRANK PIN DURING TWO COMPLETE STROKES
16X24 SINGLE DIESEL ENGINE

FIG.-1.

## Types of Engines.

*Single-Crank, Single-Cylinder.*—In the natural order of things a single-cylinder engine was first built and its construction and use is continued for all power-driving purposes except electric lighting, where the uneven impulse, on the crank, affects the light, unless an extremely heavy flywheel is used.

Fig. 1 shows the crank effort on a 16 by 24 single-cylinder engine. Fig. 2 shows the crank effort, velocity curve, and displacement of the crank-pin on a 12 by 18 triple-cylinder engine. Fig. 3 shows the same curves for 16 by 24 six-cylinder engine.

With the single-cylinder engine the standard flywheels furnished for ordinary factory work would be used. With the three-cylinder engine, in Fig. 2, a somewhat heavier flywheel was used to drive 60-cycle inductor machines on electric lighting, while with the six-cylinder engine a very heavy wheel was used, as the work is that of a suburban trolley line.

*Double-Crank Engines.*—When a four-cycle engine is made of the double-cylinder type with two cranks, the customary method is to have the cranks run together, or 360 degrees apart, causing the shaft to receive an impulse every revolution, first one cylinder and then the other receiving an ignition. This type runs very well, but for manufacturing and other reasons, another cylinder is added, and the three-cylinder engine is more nearly the accepted standard, while with the constantly increasing demand for larger engines, the four-cylinder unit must be reached, and at present, to meet requirements for a 500 h. p. unit, two three-cylinder 250 h. p. engines are coupled direct to 300 kw. alternating current generator between them.

Small engines have been built to operate on what is known as the two-cycle principle of operation, while engines operating on the four-cycle principle, but double-acting, are projected. These being aside from the direct issue of this paper will not be treated of at present.

## Design and Construction.

Fig. 4 is a section through the center of the cylinder of the 75 h. p. three-cylinder engine. As will be seen, the piston is a long trunk proportioned approximately with the length $2\frac{1}{3}$ times the diameter. This gives a minimum of bearing pressure, and wear is almost eliminated. There are four cast-iron rings fitted in grooves at the top end

and the top end of piston is tapered at least $\frac{1}{32}$ inch smaller in diameter, so as not to seize when expanded by the high temperature.

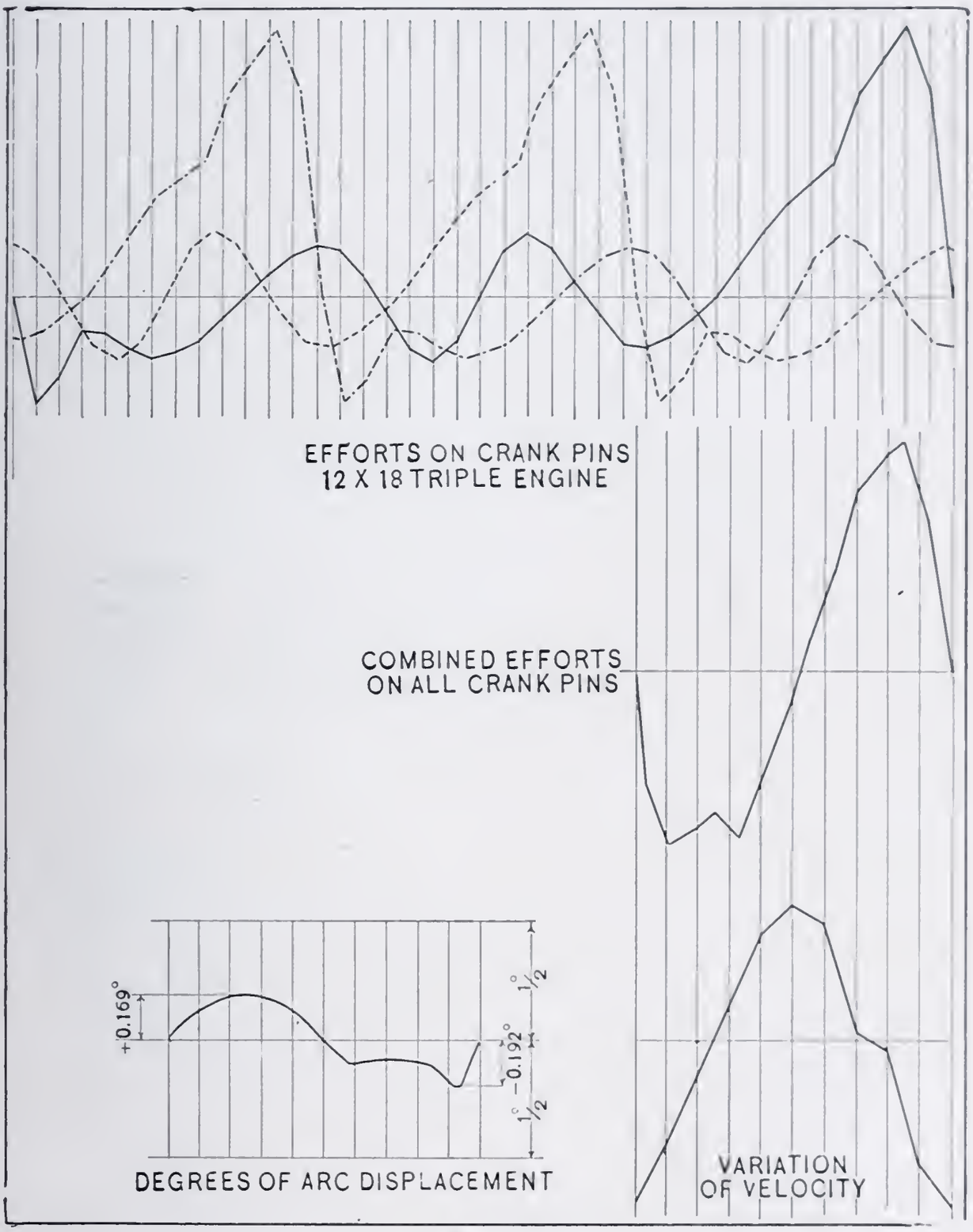



Fig. 2.

The connecting rods are solid steel forgings, the boxes also being of steel, machined out and lined with babbit at the lower end, and with a brass bushing at the upper end. The main bearings are supported on cast-iron wedges and also adjustable sideways.

Fig. 5 is a section through the center of the valves. The valve marked "A" admits the air from the atmosphere to the port, while the valve marked "B" is the exhaust valve which allows the exhaust

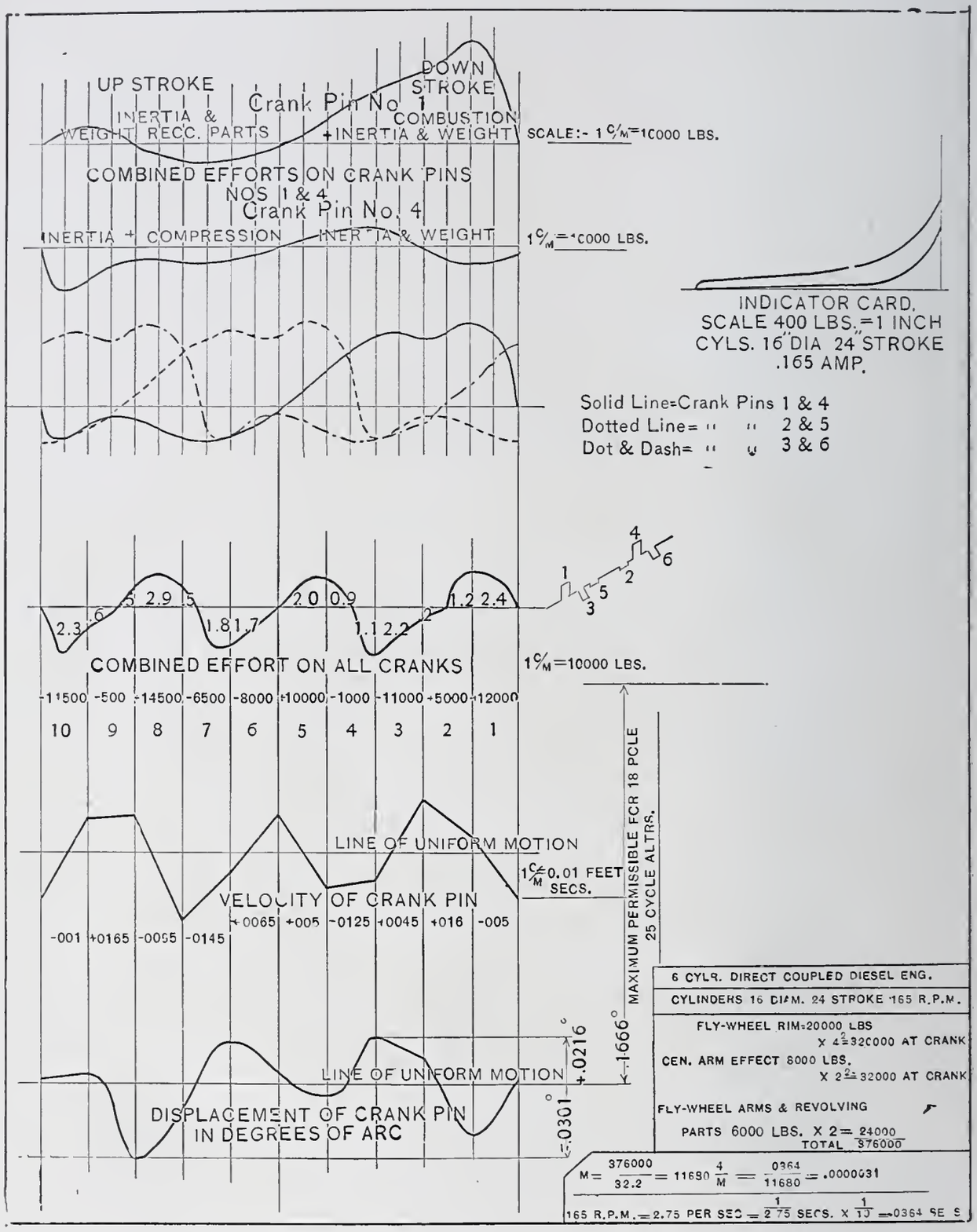



Fig. 3.

to leave the cylinder. The valve "C" is called the fuel valve and contains the chamber where the fuel oil and the compressed air from the separate compressor meet before injection into the main cylinder.

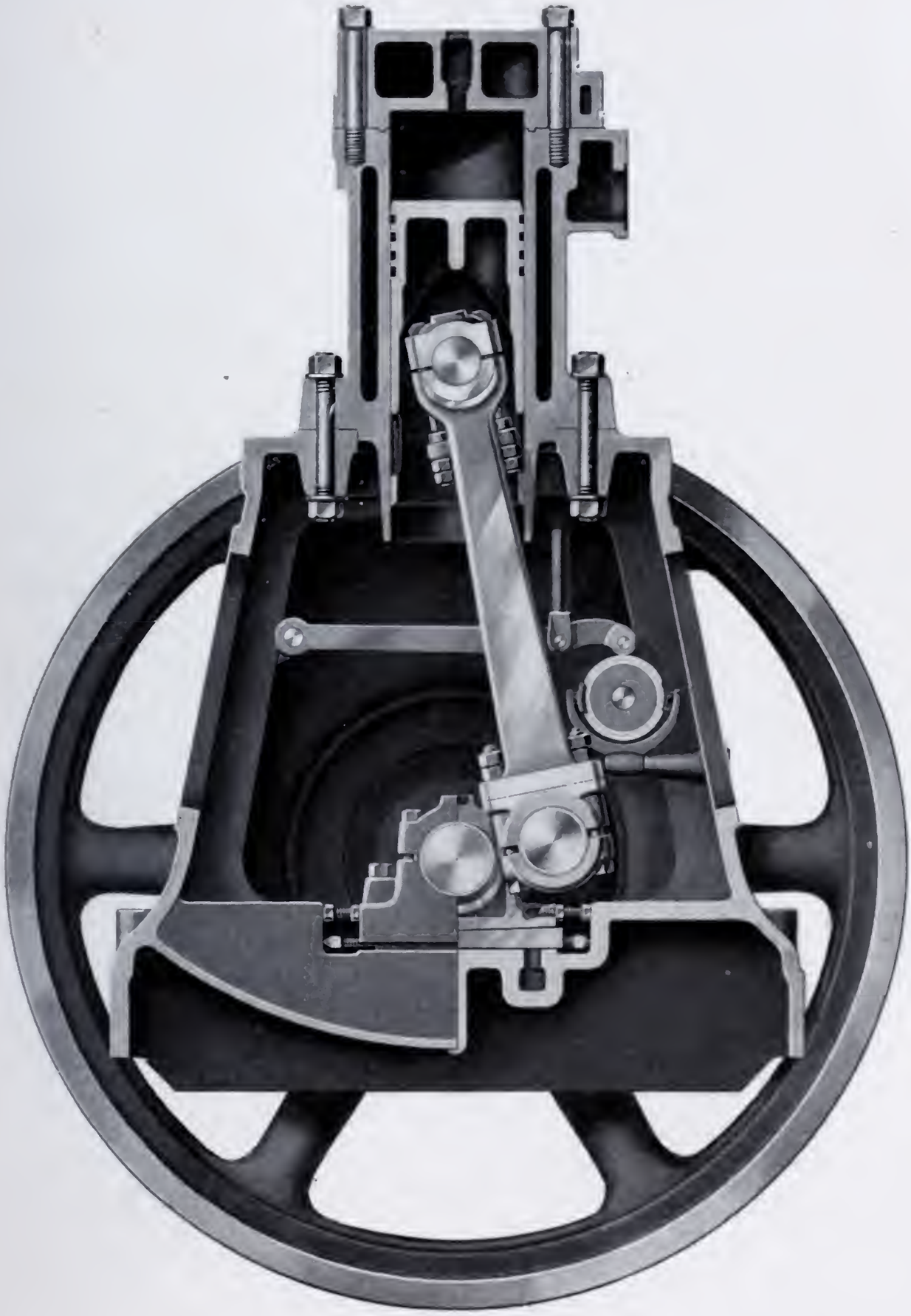


Fig. 4.

The fuel valve needle is made of nickel steel, as ordinary steel is eaten away by the petroleum, generally where the packing abrades the surface. It was found in practice that an ordinary steel needle

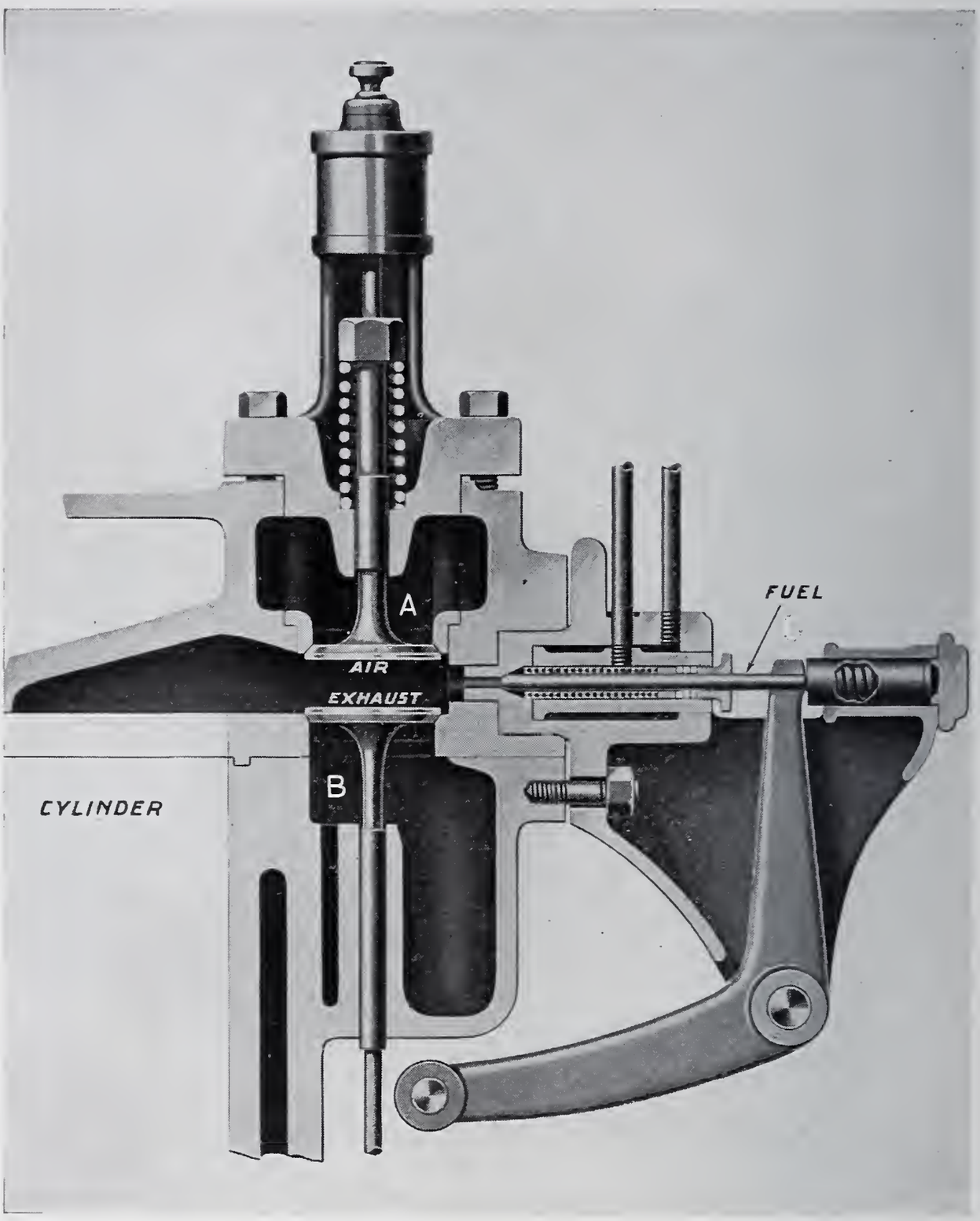



Fig. 5.

would last only three months, while no nickel steel needle has yet been replaced; in fact, they have been known to run for six months without even requiring repacking.

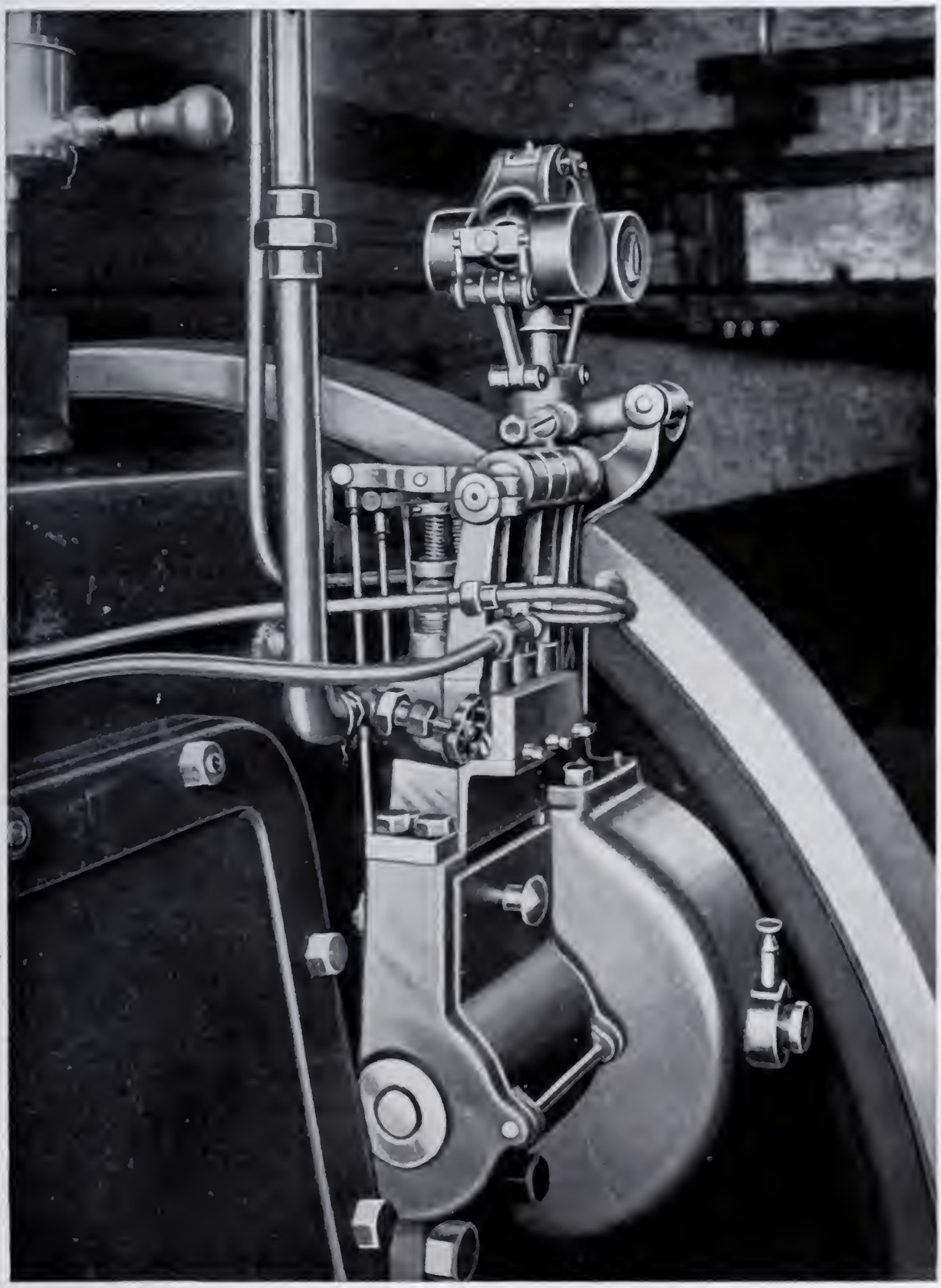


Fig. 6.

Fig. 6 is from a photograph of the oil pump and governor mechanism.

There are numerous examples where these engines are operating on variable load; one in particular at Peoria, Ill., where the load is supplied by two elevators, there being only enough lighting current

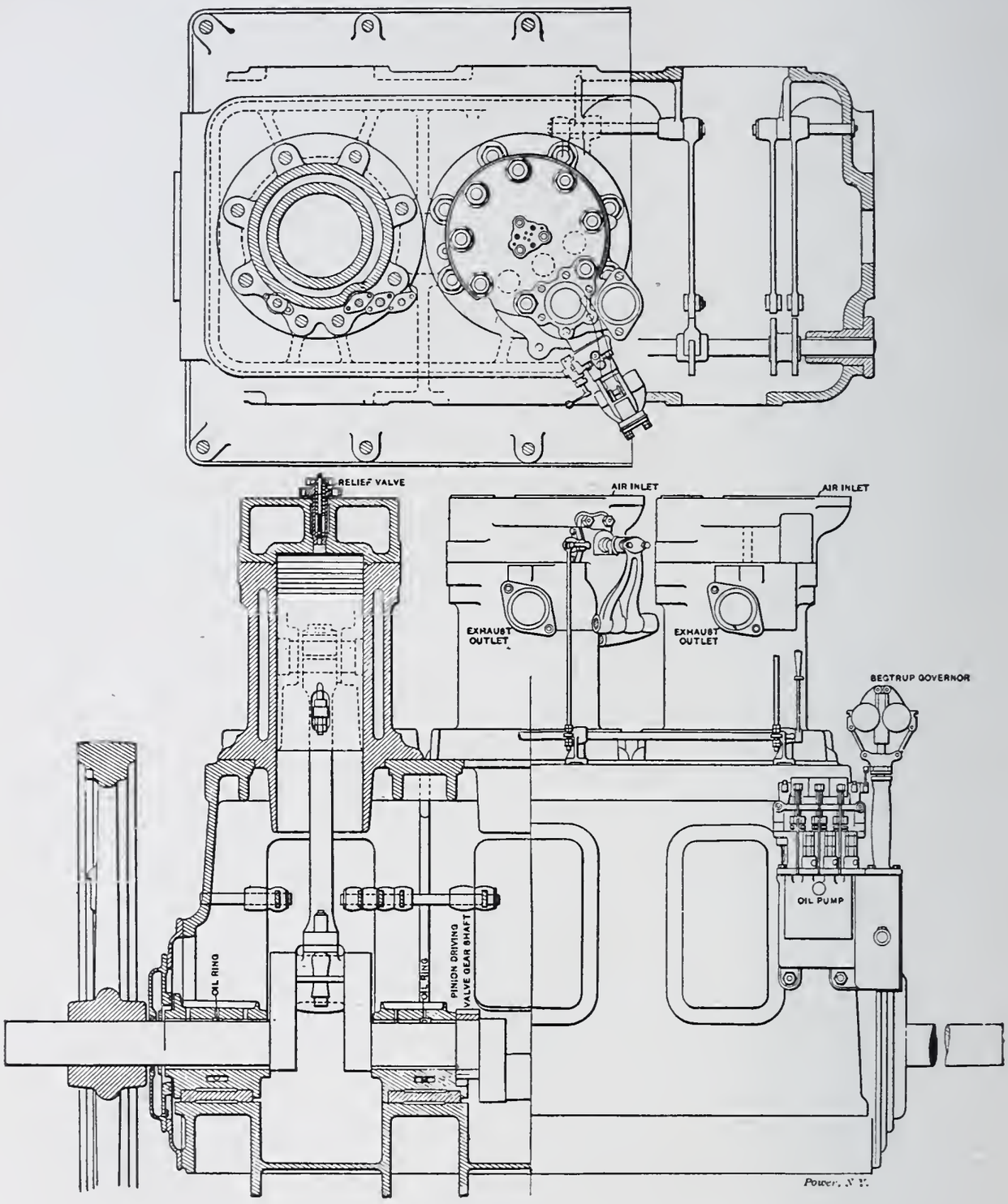



Fig. 7.

used to give a load of 5 amperes. The elevators are used intermittently all day, so that the load is constantly varying from a half kilowatt to 40 and 50, while the voltage is kept within a variation of 4

volts, the generator is over-compounded and assists in this result, but even with this load the results are remarkable.

Fig. 7 is a part section of the 120 h. p. engine. The general features of this engine are the same as already described in the 75 h. p. All crank-shafts of these engines are solid forgings throughout.

It will be noticed that in addition to the splash lubrication in the crank case, there is an oil chamber and an oil ring provided in the main bearings. This is a safeguard against the oil becoming too low in the crank case, where it might be splashed sufficiently to lubricate the connecting rod and piston, while none would reach the main bearings.

Fig. 8 is an indicator card taken from a 75 h. p. three-cylinder engine, installed in Wm. Cramp & Sons' brass foundry, Philadelphia. This engine has been in operation since January, 1903.

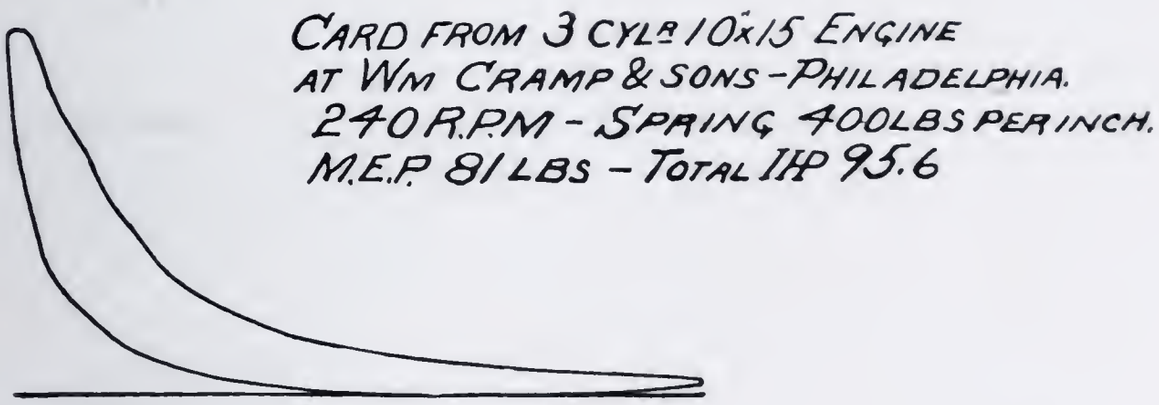



Fig. 8.

The lower temperature of the Diesel engine gives the parts subjected to heat a much longer life than in engines of the explosive type. The valves do not burn out, no admission or exhaust valve having yet been replaced, nor have any shown any bad effects from heat.

There is no deposit in the cylinder or on the valves, and they do not need to be withdrawn for examination. The first engine of the present type has not had the cylinder-head removed since its installation, two and one-half years ago. The condition of the piston rings is therefore unknown, but as the engine performs its duty, it is to be assumed that they are all right.

We might mention that the clearance between the piston and cylinder-head at the top of the stroke is $\frac{1}{8}$ inch, and it is a very good proof that there is no deposit, or some trouble would be experienced by this time. In the past eighteen months this engine has required adjustment of bearings as follows: Crosshead pin three times, crank

pin three times, main bearings three times,—which goes to show that a well-designed and well-built engine of this type does not need any more adjustment than a good steam-engine, and perhaps less than the average.

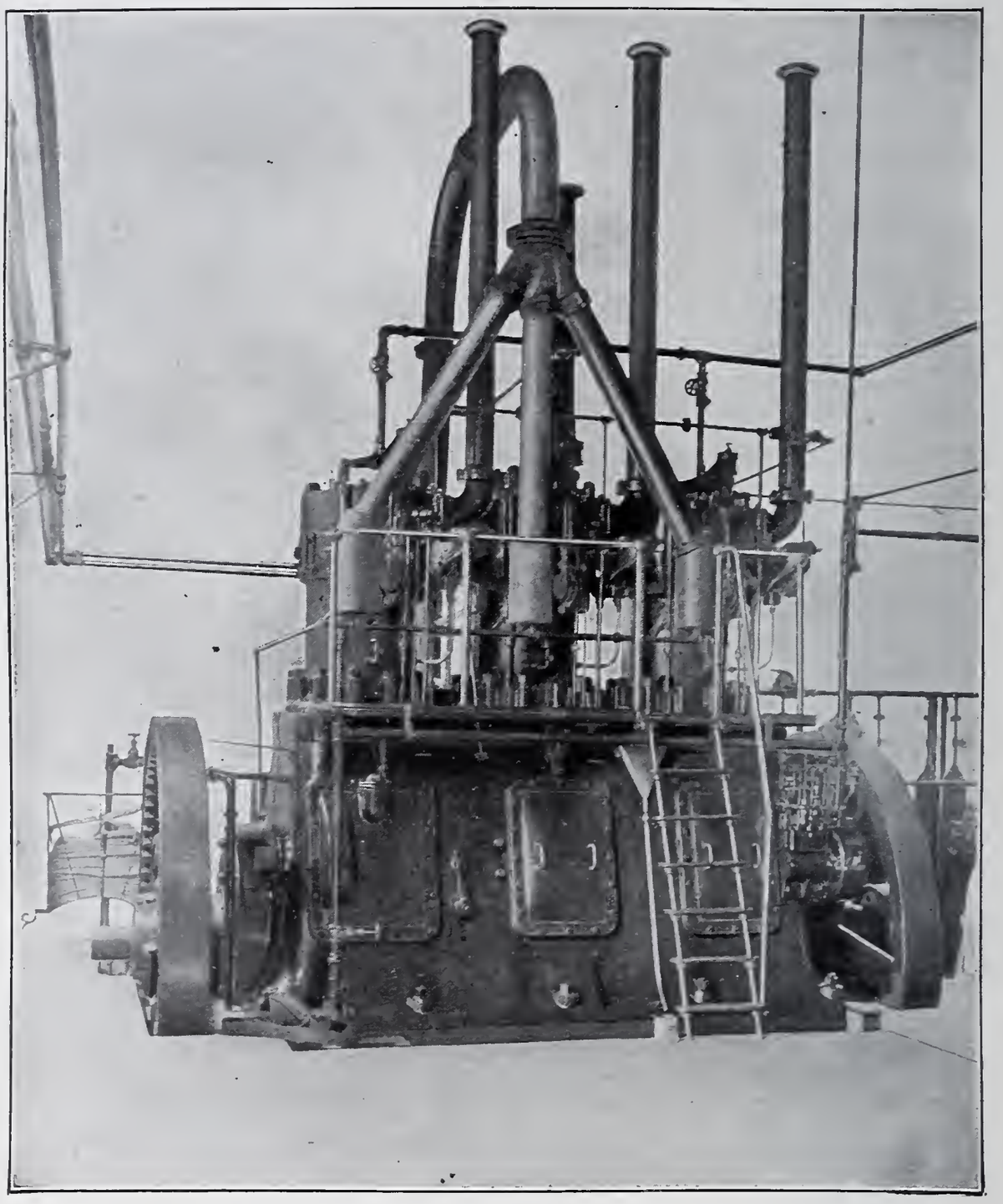


Fig. 9.

Fig. 9 is a photograph of one of the 225 h. p. three-cylinder engines, installed in the power plant of the German Tyrolean Alps, at the World's Fair, St. Louis. Three of these engines have been in constant service, driving electric generators, direct connected, since the 1st of May, giving thoroughly satisfactory service.

## DISCUSSION.

E. D. Meier.—The main difference between the Diesel and all other internal combustion engines is that the Diesel uses no "charge," as ordinarily understood in the gas-engine. I use the term "gas-engine" to cover all kinds of explosive engines, whether the gas used is fixed or permanent gas, or whether it is only made into gas for the moment. All other engines are of the explosive type, and they have to gasify their fuel before they explode it. They have to mix it with a certain quantity of air. From one gas and seven air, to one gas and eleven air constitute the limits in which explosion will take place, consequently in gas-engine practice the regulation is generally accomplished by omitting one or more charges. In the Diesel engine that is not so. We admit a fixed quantity of air for every motor stroke, and control the amount of fuel oil injected during each such stroke, and thus regulate the work done by the engine; therefore we do not have to wait for a second or third stroke, but we get our result immediately. The cycle of the Diesel engine is like that of a gas-engine, or what is known as the Otto cycle. Perhaps it should more properly be called the Beau de Rochas cycle. The Diesel engine takes a complete stroke volume of pure air into the cylinder on the first stroke; on the second, which is the compression stroke, it compresses this to from thirty to forty atmospheres, and in doing this with sufficient rapidity the heat generated is intense enough and is held long enough to ignite the oil or any fuel that may be injected; we will confine ourselves to oil because that is the only fuel for which the Diesel engine has been practically exploited. We have what is known as an atomizer, which in its simplest form is a spool of brass wire netting wound around a thimble; the oil is put into it through a small tube near the bottom, and the air brought into it through another small tube near the top, so that the air is on top of the oil The injection air comes from a separate air compressor and is at higher tension—anywhere from five to ten atmospheres higher than the air in the cylinder; up to this time there has been no oil in the cylinder at all. As the piston reaches the top of the stroke with the air in the cylinder at highest compression, the fuel valve opens and the oil is forced through the atomizer and mixed with the injection air, so that by the time it reaches the nozzle it is in the shape of a fine spray.

This nozzle is simply a small eye in a steel disc, the size dependent on the size of the engine as shown by working experience and also depending on the nature of the oil. If we build an engine intended to run on kerosene or on a very light fuel oil, we can use a smaller opening. When using heavy Texas crude oil or water-gas tar, we have to have a little larger opening. In going through this small opening it is blown out exactly as you blow out perfume from the ordinary atomizer, only we must have an excess of pressure in our injection air over the air in the cylinder, while you simply have one atmosphere of pressure in the chemist's atomizer. It is blown in and mixed in this way with the air which has just been compressed in the main cylinder. The fuel enters between the two closed main valves, entering a channel which runs into the cylinder-head, where it spreads itself entirely over the top of the piston. This is done about the moment the piston is ready to recede. As the oil

is injected it burns and increases the tension. The tension which we have to create in that injection air is not lost, because it also does work in the cylinder. The only loss we have is the friction in the air compressor, which is very small compared to the work done in the compressing air, which is utilized in the main cylinder. Of course, in making our calculations of efficiency we deduct the power required to drive the air compressor and divide the actual net remaining horse-power, which we find in the shaft of the engine, into the number of pounds of oil used. We have records for long runs as low as six and a quarter gallons of oil per hundred actual brake horse-power hours.

The President.—Can you operate two alternators in parallel, no matter what the relative positions of the two cranks are; or must the alternators be coupled so that the cranks of the two engines are always parallel?

Mr. Macpherson.—With the six-cylinder engine the cranks are coupled so that they run in pairs 120 degrees apart. If two three-cylinder units, running separately, are to be operated in parallel, the flywheels would have to be very heavy, but this has not been done by us so far.

The President.—I understand, then, that you do not have to look at the relative positions of the cranks of the two engines, at the moment when you connect the alternators in parallel on the switchboard. The point I am inquiring about is this: When the speed variation in a single revolution is very great, as is the case in some gas-engines, it may become necessary to see that the cranks of the two engines driving two alternators in parallel, are in the same *relative* positions the moment when the electric coupling of the two alternators takes place. Must this precaution be taken with your engines?

Mr. Macpherson.—The variation in position of the crank behind or ahead the mean position on those 300 kw. units will be less than $\frac{5}{100}$ of a degree. This is practically a six-crank engine with a flywheel 10 feet in diameter and a rim weight of 20,000 pounds. The generator is 18 pole, 25 cycle, and has an allowable variation ten times greater than that which the chart shows.

With the Diesel engine, the compression in the first place consists of pure air which is compressed to a pressure of 500 pounds to the square inch and at the end of that compression has a temperature ranging between 800°, when the engine is cold, and 1200°, when the engine is hot. At the end of this compression stroke there is still nothing contained in the cylinder but pure air at this temperature, but on the beginning of the next down-stroke of the piston a mixture of air and petroleum is sprayed into the cylinder for a period of 10 per cent. of the stroke. This spray is a very small one, as it is intended to burn only enough petroleum to maintain the temperature which has been already reached in the previous stroke by compressing the air; therefore at the end of the combustion period, that is to say, 10 per cent. of the downward stroke, the temperature in the cylinder should not be any greater than it was at the end of the compression stroke, with the engine running at its rated capacity. After this combustion period, the hot gases expand adiabatically until the exhaust valve opens, when the hot gases are also ejected into the atmosphere and the heat contained in that is lost; the difference between the temperature of the exhaust from a gas-engine and the Diesel, running at their rated loads, will be found to be over 400°.

At rated loads the exhaust of the Diesel is generally about 700° and will not exceed 800°, while the gas-engine reaches 1200° and over, showing that the gas-engine rejects 50 per cent. more heat in the exhaust than the Diesel, and as the whole range of temperature in the cylinder during the power stroke in the gas-engine is so much higher, there is also a correspondingly greater amount of heat rejected in the water-jacket.

As the heat is the whole source of power, it will be seen that the gas-engine has its relatively lower economy, compared to the Diesel, by reason of the foregoing greater losses.

I have used the term "gas-engine" in these remarks, but they apply equally to all forms of the internal combustion engine, which depend on instantaneous ignition of an explosive mixture precompressed in the same or an adjoining cylinder and burnt without any attempt being made to control the temperatures.

# ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, September 17, 1904.—Vice-President Horatio A. Foster in the chair. Seventy members and visitors present.

The death of Commander Wm. H. Nauman, active member, on June 15, 1904, was announced.

The Nominating Committee selected by the Board of Directors was accepted.

Dr. Henry Leffmann presented a paper on "George Washington, Engineer."

The Tellers reported the election of Messrs. Edw. Cunningham, J. Geo. Klemm, Jr., and Theodore A. Leisen to active, and H. Albert Rogers to junior membership.

# ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, September 17, 1904.—No quorum

# ADDITIONS TO THE GENERAL LIBRARY.

From University of Wisconsin, Madison, Wis.
Bulletin No. 79.

From Superintendent of Immigration, Ottawa, Canada.
The Canadian Year-Book for 1904.

From the University of Texas Mineral Survey, Austin, Texas.
Bulletin No. 8, June, 1904.

From Clifford Richardson, Long Island City, N. Y.
The Constitution of Portland Cement from a Physico-Chemical Standpoint. June, 1904.

From Charles H. Rust, City Engineer, Toronto, Canada.
Annual Report, 1903.

From John Birkinbine, Philadelphia.
The Production of Iron Ores in 1903.
The Production of Manganese Ores in 1903.

From Abner Doble Company, San Francisco, California.
An Investigation of the Doble Needle Regulating Nozzle.

From Rochester Academy of Science, Rochester, N. Y.
Proceedings, Volume 4, pp. 137–148.

From John W. Hill, Chief, Bureau of Filtration, Philadelphia.
Annual Report, 1903.

From George S. Webster, Chief, Bureau of Surveys, Philadelphia
Annual Report, 1903.